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Bulletin of the Michigan Fish Commission

No 4

~~BIOLOGICAL STATION~~
UNIVERSITY OF MICHIGAN
~~TOPINABEE, MICH.~~

A BIOLOGICAL EXAMINATION OF LAKE ST CLAIR

Great Lakes
Research

Preliminary Account of Work Done During the Summer of 1893 by the Party Maintained by the Michigan Fish Commission

By J E Reighard

With the Following Appendices

I	A List of the Protozoa and Mollusca	Frank Smith
II	The Cladocera	E A Birge
III	The Worms	H B Ward
IV	The Acarina and Insecta	R H Wolcott
V	Suggestions for an Experimental Method of Determining the Efficiency of Quantitative Nets	J E Reighard

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Bulletin of the Michigan Fish Commission

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BIOLOGICAL ST...
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A BIOLOGICAL EXAMINATION OF LAKE ST CLAIR

Preliminary Account of Work Done During the Summer of 1893 by the Party Maintained by the Michigan Fish Commission

ac
By J E Reighard

Errata.

p. 1, line 12, for have read had.
p. 17, line 6, for these read the species observed in Lake St. Clair.
„ „ line 21, for store read stave.
p. 28, § 3, line 8, second word from end of line for water read plankton.
p. 59, in the table, column 3, for 19.25 read 19.55.

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A BIOLOGICAL EXAMINATION OF LAKE ST. CLAIR.

PRELIMINARY ACCOUNT OF WORK DONE DURING THE SUMMER OF 1893 BY THE PARTY MAINTAINED BY THE MICHIGAN FISH COMMISSION.

In an undertaking like the present one, in which it is proposed to devote public funds to the prosecution of what might appear to be a purely scientific enterprise, it may be reasonably expected that some justification be offered for such a course. The following quotation from an address made by the writer before the International Fisheries Conference at Chicago, in October, 1893, is believed to meet this expectation:

"The history of the whitefish industry of the Great Lakes is well known to the members of this conference. It is presumably the history of a diminishing production in spite of a very large annual outlay for artificial propagation. The enthusiasm with which the fish culturists of twenty years back undertook the restocking of the Great Lakes was born of success in many similar enterprises. Trout and shad have been made to swarm in depleted waters. Similar results were therefore to be expected in the application of similar methods to the Great Lakes. These expectations have not been realized and fish culturists are casting about for an explanation.

"On the one hand it is asserted that the expected increase in the yield of whitefish has not been realized because of the destructive methods of fishing. The ravages of the pound net, it is said, are more than sufficient to wipe out the gain due to artificial propagation. It is maintained that if fishing methods were properly regulated the results of artificial breeding would at once make themselves felt and that, while the planting of whitefish has not resulted in increasing the supply of adult fish, it has prevented any large reduction in that supply, so that many grounds, which now pay for the fishing, would have been utterly exhausted but for artificial propagation. The remedy for the present condition of things is believed to lie both in legislation controlling fishing methods, and in a still greater extension of artificial propagation.

"On the other hand, it is claimed that if the artificial propagation of whitefish *were successful*, it should result in an increasing yield in spite of exist ing methods of fishing. The remedy does not lie in restrictive legislation; it lies rather in an increasing of the effectiveness of methods of artificial propagation and perhaps also in an increase of the annual output of artificially hatched fish.

"The first view is held for the most part by fish culturists, who favor restrictive legislation and increased facilities for artificial propagation.

"The second view is held for the most part by fishermen, many of whom are not yet convinced of the value of artificial propagation.

"When one who is neither fish culturist nor fisherman attempts to discover the grounds upon which the various opinions are based, he very soon finds that there are but few recorded facts.

"In order to know whether the number of whitefish is increasing or diminishing for any locality or for all localities, it is necessary to have statistics extending over a term of years. Statements based on statistics which are taken in two years separated by an interval of five or ten years, are nearly valueless for purposes of comparison for the reason that such statistics do not and cannot take into account the climatic conditions which make one year favorable and another year unfavorable. The fact that in the year 1880 the number of whitefish marketed was greater than in 1890, does not prove that the number of whitefish has diminished in this interval; it proves only that the number *caught* in 1890 was less than the number *caught* in 1880. This may have been due to a diminution in the number of fish, but it may also have been due to storms during the fishing season of 1890. Statistics to be conclusive should enable us to compare the *average* yield for the ten years 1870 to 1880 with the average yield for the ten years 1880 to 1890.

"No such continuous series of statistics is in existence, so that the assertions concerning a diminishing yield of whitefish rest either on a comparison of these statistics of isolated years or on the statements of fishermen concerning certain localities.

"If we inquire into the facts concerning the sufficiency of the present methods of artificial propagation, we find that so far as concerns the whitefish there is no question as to the success of the earlier stages of the process. Several hundred million ova are taken annually and placed in the hatcheries and of these usually from 80 to 90 per cent are hatched and placed in the waters of the Great Lakes—165,000,000 in Lake Erie alone in 1888.

"This is very nearly all that is known about these young whitefish. About their food habits we know only that in captivity that they eat certain species of Crustacea. Whether in their natural habitat they eat other animals in addition to these Crustacea or in preference to them we do not know. It is uncertain at what age they begin to take food or how much they require. We do not know their natural enemies. We do not know whether they thrive best in running water or in standing water, in shallow water or in deep water, whether at the surface or near the bottom. What changes of habitat or of food habits the fish undergo as they grow older is a still deeper mystery.

"Our problem is to place young whitefish in the Great Lakes under such conditions that as large a number as possible of them shall grow into adult fish. It is clear that of one of the elements in this problem namely, the *whitefish,* we know but little.

"*What, then, do we know of* the other elements of the problem, the Great *Lakes themselves? Individual* naturalists have made efforts from time to time to study one or another of the groups of animals living in the lakes. These efforts have always been circumscribed by the facilities at hand, by the time that could be devoted to the subject, by the small area examined, or by the small number of animals taken into account. Although much excellent work has resulted from these efforts it remains true that there has been thus far no attempt to secure an accurate knowledge of all the conditions existing in any one locality, and no attempt to study exhaustively a single group of the animals and plants of the lakes. We are still at the beginning so far as concerns a knowledge of life conditions in these lakes, the conditions with which we surround our young whitefish. If we could assume that the conditions are uniform over the whole area of the Great Lakes, then since the young whitefish are native to these lakes, it might be a safe conclusion that they will find the conditions in one locality as well for them as in another. But there are no facts which support the view that the conditions are uniform over the lakes.

"We are thus in the position of bringing together under unknown conditions, two things, both of unknown character; and we expect as a result to get a third thing, marketable whitefish. Should we not pursue our object more intelligently by first determining the characteristics of the materials with which we have to work? It was with this object in view that the Michigan Fish Commission in the summer of 1893 established a scientific laboratory on Lake St. Clair. This lake is readily accessible from the Detroit hatchery at the season when whitefish are planted. Whitefish are caught in certain parts of the lake in considerable numbers in the spawning season, so that it is probable that spawning grounds of this fish are found along the west shore of the lake near its outlet. In establishing a laboratory on the lake, the Fish Commission hoped, therefore, to accomplish two things.

"(1) To study carefully and in the broadest possible way the life of the lake. After examining the physical characteristics of the lake, such as the color, transparency and chemistry of the water, a study of this sort should include a determination of the kinds of animals and plants in the lake. Every species should be sought out, carefully described and figured, and a specimen of it preserved. Then the habits of each species should be known, its habitat, its food, its enemies and its parasites. The numbers of animals and plants of each species in a given volume of water should be determined and the variations in these numbers in different parts of the lake and at different seasons of the year. Such a collection of data would form a complete picture of the biology of the lake.

"(2) It was hoped that young whitefish might be captured in the lake by suitably arranged nets, and that it might thus be possible to determine the food habits of the young fish, and the other conditions under which they are found in nature.

"Should both these objects be accomplished, we should be in a position to determine where in the Great Lakes are to be found the conditions favorable to the whitefish fry."

An enterprise of this sort cannot, of course, be carried very far in a single season. No very large body of facts can be collected in so short a time, nor has it been possible in the six months since the close of the season, to thoroughly work over the data at hand, so as to get out of them all the conclusions which they may be supposed to yield.

The following report is therefore preliminary. Effective fish cultur and the regulation of the fishing industries of the lakes, must depe upon a *complete* knowledge of the life of these lakes and of the physical conditions that encompass and maintain that life. To acquire this knowledge is a labor of many men and of many years. He is the most successful farmer who knows the value of different sorts of soil and how to fertilize them most economically, who knows how and where and in what quantities his seeds should be planted, who knows when and how and with what apparatus his crops should be gathered, who knows what food should be fed to his stock and in what quantity. The fisherman is almost wholly ignorant of the corresponding facts in his own calling. Of his soil—the lake—he knows but little, that it could be fertilized has not occurred to him, he never plants, while the planting that is done for him is at random and without knowledge of the soil upon which the seeds fall; he reaps continuously without restraint and with every possible form of deadly apparatus. The remedy for all this, the only remedy is, I believe, untramelled and extended investigation of the lakes from every point of view. It was with the purpose of carrying on such an investigation that an examination of Lake St. Clair was undertaken.

EQUIPMENT AND METHODS.

A laboratory was located at New Baltimore, near the head of Anchor Bay which is the northeastern part of Lake St. Clair. Through the kindness of Mr. Gilbert Hatheway, the party had the use of the second story of a large warehouse situated on his pier. By the use of temporary sheathing of heavy paper this was transformed into a comfortable room. Four large and very rigid laboratory tables, especially designed for their portability, were placed at the windows and accommodated two workers each. The spaces on the wall were filled with temporary shelving for books and apparatus and two large tables were provided for general work. At one of the windows was placed a large zinc topped table arranged to hold a dozen small aquaria to which running water was supplied from a tank outside the building. On the wharf without was erected a shed which sheltered three large aquaria supplied with water from a special tank. In these aquaria the largest fish of the lake could be kept under observation.

The laboratory was supplied with small boats. For more extended trips and for use with the heavier collecting apparatus there was a small steamer, the Ben Hur of Detroit, a boat of about ten tons burden. She has a very roomy cabin and was found to serve every purpose admirably.

A considerable collection of pertinent literature, as well as microscopes and the other usual laboratory apparatus, was loaned by the University of Michigan. A liberal supply of the usual glassware and reagents and of the minor apparatus was provided by the Fish Commission. The collecting apparatus included the usual hand nets, tow nets and dredges. Besides these there were some forms of nets not in common use. The ordinary form of deep sea dredge was found to slip over the hard clay bottom or over the thick matting of Characeæ which covers this bottom, so that it usually came up empty. In its place was used a dredge made as follows: An iron band 2 inches broad, ⅜ of an inch thick and 4 feet 6 inches long is cut along one edge into a row of triangular teeth each an inch broad and an inch high. These teeth are sharpened and bent so as to form an angle of about 15 degrees with the rest of the band, which is provided with holes into which a net may be laced. The band is then bent on the broad side into the form of an equilateral triangle with the teeth inclined outward.

In each angle is welded a stout ring for the dredge rope, and also an iron rod 2½ feet long which projects at right angles to the plane of the triangle and from the edge of the band opposite the teeth. A flat net of inch mesh is supended from the triangle and its bottom is lined for about a foot with coarse cotton cloth. The whole net frame has thus the form of a triangular prism and when dragged along the bottom always rests upon one side, so that the teeth at the edge of the frame act with great effectiveness in loosening objects imbedded in the hard clay bottom. This net is modeled from one exhibited among the apparatus of the Plankton Expedition in the German University Exhibit at the World's Fair.

Another piece of apparatus of great value is the net designed by Prof. E. A. Birge for collecting Cladocera, described in Trans. Wis. Acad., vol. viii, 1891. It is indispensable on weedy bottoms or shores.

It is well known that the ordinary tow net when weighted so as to be used on the bottom either runs at an unknown distance from the bottom, or if it reaches the bottom fouls in the weeds or fills with mud or sand. We therefore make use of the tow net supported on four flat iron runners which are welded to the iron net ring. These runners extend for about 30 inches at right angles to the plane of the net ring and are then bent toward one another and riveted together at a point opposite the center of the net ring and three feet from it. The net thus hangs within the frame formed by the runners and its mouth is held about two inches from the bottom. This proved an excellent device for collecting bottom forms free from weeds or mud.

For quantitative work we used a vertical net which is more fully described in another place.

Six persons worked in the laboratory from July 15 to Sept. 15. They were:

Prof. J. E. Reighard, director; quantitative work, Crustacea and vertebrates.

Dr. H. B. Ward, associate professor of zoölogy, University of Nebraska, Lincoln, Neb.; worms.

Mr. Frank Smith, instructor in zoölogy, University of Illinois, Champaign, Ill.; Protozoa and Mollusca.

Dr. Robert H. Wolcott, Ann Arbor, Michigan; Insecta and Hydrachnida.

Mr. H. S. Jennings, assistant in animal morphology, University of Michigan; Rotatoria, sponges, and Bryozoa.

Mr. A. J. Pieters, assistant in botany, University of Michigan; plants.

Two employès of the Fish Commission, Mr. Dwight Lydell and Mr. Jesse P. Marks, rendered valuable service in collecting, fishing, and in otherwise furthering the interests of the laboratory.

Each person had charge of that portion of the subject set opposite his name. These gentlemen worked enthusiastically and without compensation, in the interest of science, so that whatever results have been reached are largely due to their unselfish devotion.

In addition to the work which has been done by the laboratory staff, the following gentlemen have undertaken to work up the groups set opposite the names.

Dr. R. Blanchard, Paris, France; the leeches.

Dr. E. A. Birge, University of Wisconsin; the Cladocera.

Dr. G. Eisen, San Francisco; the Oligochæta.

Prof. C. Dwight Marsh, Ripon, Wis.; the Copepoda.

Dr. W. M. Woodworth, Harvard University, Cambridge, Mass.; the planarians.

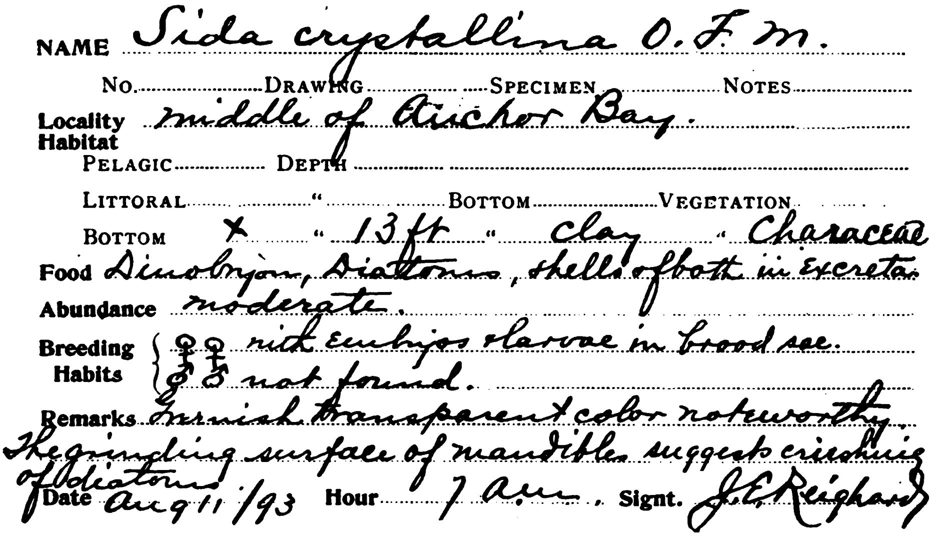
Mr. Bryant Walker, Detroit, has identified most of the Mollusca.

Aid has also been received in the identification of the Characeæ from Dr. T. F. Allen of New York City, and in the Desmidaceæ and unicellular algæ from Mr. L. N. Johnson of the botanical department of the University of Michigan.

The first six weeks were spent in qualitative work, that is in making a list of the animals and plants of the lake, in noting their habits and the way in which they were associated, and in preserving specimens, drawings and records of observations. Every morning and frequently again in the afternoon a man was sent out into the bay with the different sorts of nets. With the tow nets were obtained the smaller animals and plants floating in the water, at the surface, in mid-water, and near the bottom. The forms attached to the bottom or concealed among the water plants were collected by means of the toothed dredge and the Birge net. Collections were also made near the shore with the same apparatus. All the materials were brought to the laboratory and were ready for examination upon the arrival of the laboratory force. Each worker then sorted out from the collection the materials belonging to him. This method of working was kept up until it was felt that all the inhabitants of the lake, except possibly a few rare or occasional ones had become familiar. The living specimens were studied in all cases and material was preserved for future study. Final identifications were attempted only in the cases where the original literature in the laboratory was ample for the purpose.

At the same time that collections were being made of the smaller inhabitants of the lake, gill nets were set for the capture of fish, while other fish were purchased from the fyke-net fishermen who landed their catch every day at the laboratory dock. The stomachs of several hundred of these fish were examined and the contents preserved with the purpose of determining the food habits of the fish. At the same time the fish were systematically searched for parasites and many important biological data were collected concerning these forms. A more detailed report on them is in preparation by Dr. Ward.

In order to keep a continuous and systematic record of the material examined, use was made of blank forms in which each person entered the species observed by him. These blanks are of two sorts, one intended to give the more important data concerning the individual animals and plants, and the other intended to show how these animals and plants are associated together under different conditions. The following is a sample of what may be called the individual blank:



NAME Sida crystallina O. F. M.

NO. DRAWING SPECIMEN NOTES

Locality middle of Anchor Bay.

Habitat

PELAGIC DEPTH

LITTORAL " BOTTOM VEGETATION

BOTTOM × " 13 ft " clay " Characeae

Food Dinobryon, Diatoms, shells of both in excreta.

Abundance moderate.

Breeding Habits { ♀♀ with embryos & larvae in brood sac. ♂♂ not found.

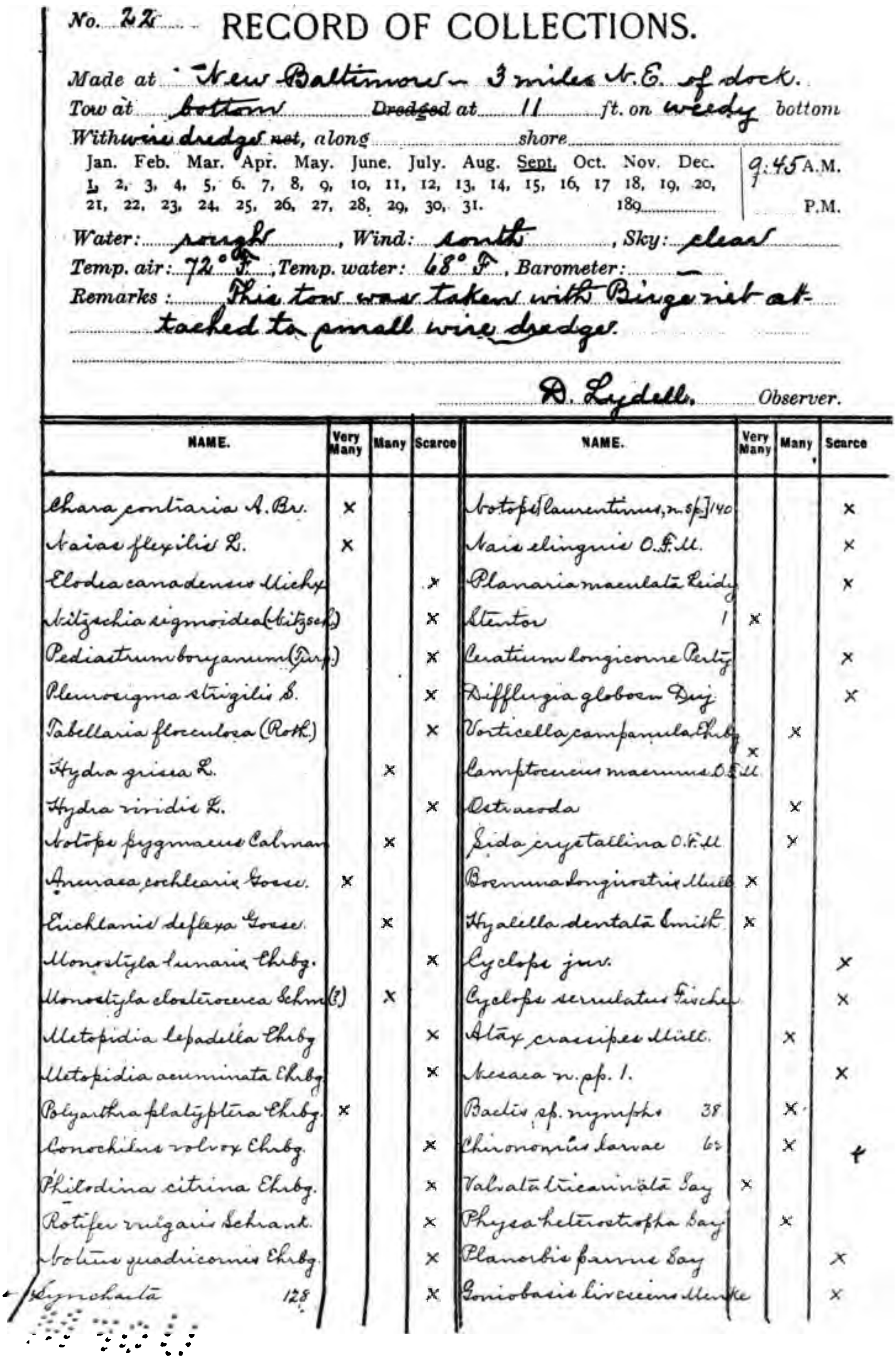
Remarks Greenish transparent color noteworthy. The grinding surface of mandibles suggests crushing of diatoms.

Date Aug 11/93 Hour 7 a.m. Signt. J. E. Reighard

This blank gives the results of the observations of a single day on a single species of Sida, the name of which appears at the top of the card. Whenever this same species was observed under different circumstances a new card was made for it. By sorting out all the cards referring to a single species, one has at hand in condensed form all the facts recorded concerning it.

These blanks did not take the place of note books, but were meant merely to condense and systematize the records made in the note books.

The other form of blank may be called the *collective* blank. A sample of it appears below. It is a modification of a form used at Mr. Agassiz's Newport laboratory.



No. 22 RECORD OF COLLECTIONS.

Made at New Baltimore – 3 miles N.E. of dock.
Tow at bottom *Dredged at* 11 *ft. on* weedy *bottom*
With wire dredge net, *along* .... *shore* ....
Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. 9:45 A.M.
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 18, 19, 20,
21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31. 189........ P.M.
Water: rough, *Wind:* south, *Sky:* clear
Temp. air: 72° F., *Temp. water:* 68° F., *Barometer:* —
Remarks: This tow was taken with Birge net attached to small wire dredge.

D. Lydell. *Observer.*

NAME.	Very Many	Many	Scarce	NAME.	Very Many	Many	Scarce
Chara contraria A. Br.	×			Notops [laurentinus, n. sp.] 140			×
Naias flexilis L.	×			Nais elinguis O.F.M.			×
Elodea canadensis Michx			×	Planaria maculata Leidy			×
Nitzschia sigmoidea (Nitzsch)			×	Stentor 1	×		
Pediastrum boryanum (Turp.)			×	Ceratium longicorne Perty			×
Pleurosigma strigilis S.			×	Difflugia globosa Duj.			×
Tabellaria flocculosa (Roth.)			×	Vorticella campanula Ehrbg		×	
Hydra grisea L.		×		Camptocercus macrurus O.F.M.	×		
Hydra viridis L.			×	Ostracoda		×	
Notops pygmaeus Calman		×		Sida crystallina O.F.M.		×	
Anuraea cochlearis Gosse.	×			Bosmina longirostris Müll	×		
Euchlanis deflexa Gosse.		×		Hyalella dentata Smith	×		
Monostyla lunaris Ehrbg.			×	Cyclops juv.			×
Monostyla closterocerca Schm (?)		×		Cyclops serrulatus Fischer			×
Metopidia lepadella Ehrbg			×	Atax crassipes Müll.		×	
Metopidia acuminata Ehrbg			×	Nesaea n. sp. 1.			×
Polyarthra platyptera Ehrbg.	×			Baetis sp. nymphs 38		×	
Conochilus volvox Ehrbg.			×	Chironomus larvae 62		×	+
Philodina citrina Ehrbg.			×	Valvata tricarinata Say	×		
Rotifer vulgaris Schrank.			×	Physa heterostropha Say		×	
Noteus quadricornis Ehrbg.			×	Planorbis parvus Say			×
Synchaeta 128			×	Goniobasis livescens Menke			×

The blank given enumerates only a part of the haul of that number and date; but forty-four out of seventy-six entries recorded in the original have been reproduced here. Without being selected to present an average of the hauls, it is still a fair sample of the record. The numbers appended to the name of a genus refer to the note-book of the investigator who made the record and mark a species which is either new or not yet identified.

Blanks of this form were passed from one worker to another and each person entered in them the forms which he had found as taken in a certain net at a certain time and in a certain location. The blanks thus serve to show the way in which the forms are associated together and their relative numbers under different conditions at different times. To properly fill one of these blanks was usually the work of six observers for the greater part of a day.

For the records of parasites there was a third form of blank designed by Dr. Ward, and shown in the report on the parasites, contained in the appendix. It is intended to bring together certain data concerning the animal infected and the numbers and kinds of parasites.

A similar record was kept of the contents of the fish stomachs, but no special blank was used for this purpose. It is desirable to use a blank for this also.

Detailed reports are now in preparation by the various members of the laboratory staff and by others who have undertaken to work up special subjects. The report on the plants and that on the Rotatoria have been published as Bulletins of the Michigan Fish Commission. Other reports of similar scope will be published as soon as completed. Some which are briefer or preliminary in character are appended to this paper.

STATEMENT OF RESULTS.

Lake St. Clair stretches from 42° 18′ to 42° 42′ north latitude and from 82° 25′ to 82° 55′ west longitude and lies at an elevation of about 580 feet above the sea. It has roughly the form (see map at end of report) of an equilateral triangle with rounded angles. Each side of the triangle, measured in a straight line, is from twenty-five to thirty miles. The southern and shortest side of the triangle is nearly straight and runs east and west. From its western end the western side inclines toward the east as it extends northward. It is broken at about the junction of its northern and middle thirds by the projecting delta of the Clinton river. The third side of the triangle looks toward the northeast. In the middle of this northeastern shore the lake receives the waters of the St. Clair river which carries the overflow of the three upper lakes. At its entrance into Lake St. Clair the river breaks up into several channels, each of which again divides once or twice so that the water of the river enters the lake through nine well-defined mouths of varying sizes. These mouths are scattered for a distance of twenty miles along the northeast shore and discharge their waters into the lake at a considerable velocity. Between the channels which diverge from the main river to these mouths, is swampy shifting ground, which forms an enormous delta overgrown with rushes and covered usually by a foot or more of water. These are the celebrated St. Clair Flats. The banks of the channels only are usually formed of moderately firm ground and it is upon them that numerous summer residences and hotels have been built. By the projecting delta of the Clinton river and that of the St. Clair river the northwest corner of the lake is partly isolated to form Anchor Bay.

The lake has an area of 410 square miles (Schermerhorn 87). The shore line of the whole lake measured on the government chart, is about 187 miles. Of this the shore line of the delta[1] of the St. Clair river contributes 104 miles, while that of the remainder of the lake contributes but 83 miles. Seligo (90) has expressed the absolute shore development of lakes by dividing the length of the shore line by the square root of the surface. The absolute shore development of Lake St. Clair is thus $187 \div \sqrt{410} = 9.23$. Seligo further expresses the relative shore development by using the circle as a unit. The absolute shore development of a circular lake is $\frac{2\pi r}{\sqrt{\pi r^2}}$ which, in case $r = 1$, is 3.54. The relative shore development of Lake St. Clair is thus $9.23 \div 3.54$ or 2.607. The greater part of the shore line is that belonging to the delta of the St. Clair river. If this stretch of delta shore were replaced by a portion of shore such as extends from Milk River Point to New Baltimore, the total shore line of the lake would be but 109 miles. The absolute shore development reckoned on the basis of a shore line of 109 miles is 5.38 while the relative shore development becomes 1.519.

The water poured into the lake at the rate of 225,000 cubic feet per second through the many mouths of the St. Clair river, converges to the southwest corner of the lake, whence it flows toward the west through the Detroit river. There is thus produced a current in nearly all parts of the lake. In most places this current is slight, but near the mouths of channels it reaches a very considerable velocity.

The shore of the deltas of the St. Clair and Clinton rivers and of the many smaller deltas which occur about the shore of the lake at the mouths of smaller streams, are of course low and marshy and formed of a characteristic spongy loam. The remainder of the shore is formed by a bluff of clay (the sea cliff) which contains a considerable admixture of sand or gravel. The sea cliff varies in height from 2 or 3 to 15 or 20 feet. It is being continually eroded by the action of the waves so that it is customary to protect it by sea walls or by a covering of brushwood. The erosion washes away the fine clay composing the cliff. This clay is carried by currents and waves into the deeper water where it is either deposited on the bottom or removed by the current. The coarser particles of sand and gravel which are mixed with the clay are deposited along the shore and help to form little stretches of sandy or gravelly beach. The bottom of the lake is composed of fine blue clay—like that of the shore. The clay has been washed out of the superficial layer of the bottom by the long continued action of the waves and currents so that there is left nearly everywhere a stratum of fine sand or gravel which separates the clay of the bottom from the overlying water. This stratum is not usually more than one or two inches thick, and is often composed of particles of such fineness as to warrant its popular name of mud. A microscopical examination has not revealed in it any organic remains.

In most lakes the particles eroded from the shore by the action of the waves are deposited near the shore in the form of a terrace, called by geologists the "lake terrace." The lake terrace is a nearly level zone of the lake bottom which extends on all sides from the shore for a considerable distance towards the center of the lake. At its lakeward margin the terrace slopes sharply to the bottom of the central part of the lake—forming that which is known as the lakeward slope of the terrace. Since the terrace is formed by the erosive action of the waves it is composed of sand, gravel and fine loam or clay washed from the sea cliff. Large boulders of coarse gravel, on account of their weight, are deposited near the shore, finer gravel and sand are carried out to some distance from the shore, while the finest sand, the mud and clay are carried to the lakeward margin of the terrace. Passing from the shore to the lakeward slope of the terrace, the latter is found to be made up of successive particles of continually diminishing size. In lakes of this sort the water covering the lake terrace is shallow and of nearly uniform depth. On the lakeward slope of the terrace the water deepens abruptly, and as one proceeds from the bottom of this slope toward the center of the lake the water gradually deepens, reaching its greatest depth near the center of the lake. This is expressed in the section of an ordinary lake shown in figure 1.

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[1] The delta varies greatly in extent and form of its shore according to the stage of the water. The measurements are therefore only approximate. They are carried directly across the mouths of the channels.

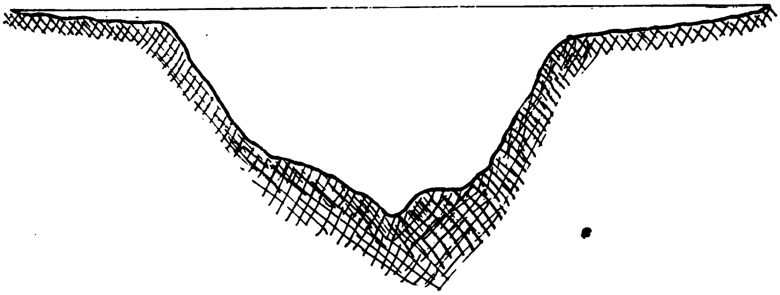

FIG. 1.—Typical Lake.

Lake St. Clair has no well-defined terrace. The depth of the water, therefore, increases gradually from the shore to the central area of the lake. Over this central area, which is perhaps a fifth of the whole lake area, there is a nearly uniform depth of about twenty feet. The unusual shallowness of the lake may be realized from the following statement. On a chart drawn to a scale of 1–50,000, the width of the lake at latitude 42° 25′ is about 30 inches. On the same scale the greatest depth would be represented by a line 1–200 of an inch in length. Thus a line 30 inches long and departing from a straight line at its middle by 1–200 of an inch would represent a cross section of the lake. To the eye such a line appears perfectly straight.

The absence of a terrace in Lake St. Clair is to be accounted for by the (in a geological sense) comparatively recent formation of the lake. Within recent times the lake, like the other great lakes, covered a much larger area than it now occupies. The water subsequently receded until the lake reached its present size. The present lake bottom is, therefore, only the central more level portion of the original lake basin and is without a terrace. The time that has elapsed since the lake reached its present size has not been sufficient to form a new terrace. The currents further work against the rapid formation of a terrace by carrying out into the center of the lake or removing from it entirely the material which would be otherwise deposited to form a terrace.

No attempt has been made to measure the transparency of the water of the lake. It has not that remarkable transparency that characterizes the waters of the northern lakes. This is to be accounted for by its meagre depth. The shallow water near shore is always much roiled even by moderate waves, apparently on account of the fine particles of clay in suspension. A zone of this roiled water extends for perhaps a quarter of a mile from the shore and disappears only in very quiet weather. Probably in very rough weather the bottom is affected by the wave action in even the deepest water. The whole lake would then be roiled. We had no opportunity to observe this.

The temperature of the water in September varied from 18° to 21° C (65° to 70° F.) and there was but little difference between the temperature at the bottom and that at the top. In the deepest water this difference was not more than 1°C.

I know of no chemical analysis of the lake water.

The salient physical characters of Lake St. Clair are: *The existence of currents, the great shallowness, the lack of transparency in the water, the absence of a terrace, the contrast between the shore line on the northeast shore of the lake and that of the remainder of the lake.*

THE FAUNA AND FLORA OF THE LAKE.

The first six weeks of our stay on the lake were spent in an attempt to make a record of the animals and plants occurring in it, and to gather such data as was possible concerning them. The following summary will indicate what was accomplished in this direction. For a fuller discussion consult the various appendices to this report and the bulletins of the Michigan Fish Commission, which deal more exhaustively with the individual groups.

Plants: The plants of a lake may be roughly divided into two groups, (1) the larger plants which grow near the shore in shallow water and which cover the bottom in water of moderate depth, and (2) the microscopic plants, which are either attached to the larger plants or float free in the water. In the open water in the middle of a lake where no plants are visible to the naked eye, all vegetation appears to be absent. Such water nevertheless contains great numbers of minute floating algæ, so that the vegetation borne by it is equal in amount to that growing on a sparsely covered meadow (Seligo 90). The plants occurring in Lake St. Clair are enumerated in the report of Mr. Pieters, which has been published as Bulletin No. 2 of the Michigan Fish Commission. (Among the minute floating plants I desire to call particular attention to the occurrence in quantity of *Clathrocystis œruginosa,* as reported by Mr. Pieters.) The list includes 158 species, of which 106 are microscopic. Mr. Pieters points out that the plants which grow in the shallow water along the shore are arranged in well marked zones, each characterized by the presence of certain genera. Owing to the absence of a terrace and the consequent very gradual increase in the depth of water, these zones overlap or pass into one another more gradually than is the case in lakes with a well defined terrace.

The bottom of the lake, wherever examined, was found to be covered by a growth composed mostly of *Chara.* The *Chara* encroaches upon the zone of plants which borders the shore. It is probable that it also covers the bottom of the whole lake. In most parts of the lake the plants composing this bed of *Chara* are as numerous as those in a thrifty field of clover.

At least three factors influence the abundance of plants in a lake:

1. The amount of matter in solution in the water. Just as the productive capacity of a field is dependent on the richness of its soil, so is the productive capacity of a lake dependent on the richness of its water, that is, upon the amount of material in solution in the water and suitable for the nourishment of water plants. The microscopic plants are wholly dependent on this material for their food supply, while even those plants that are rooted to the bottom are largely, but in different degrees, dependent on the same source of food. The food material is brought into the lake by the action of the waves in eroding its shore, by the streams which drain its basin, by floods, winds and rains. It consists in part of substances washed from the soil or air and in part of dead animals and plants, or fragments of them. A part of it reaches the lake in solution, while another part is in suspension. The part in suspension settles to the bottom of the lake and there, if organic, it slowly decays and its products pass into solution. Its amount is dependent on the extent of the drainage basin of the lake and upon the richness of the soil of this basin. It is also dependent on the length of the shore line of the lake, since the longer shore line presents more material to the erosive action of the waves. Thus the supply of plant nutrition in a lake is continually added to from without. It is also continually lost through the outlet of the lake, so that the amount of it in the lake remains constant. The amount of this material in the water of Lake St. Clair has not, to the knowledge of the writer, been determined by chemical analysis. Susta (87) has found it possible, and profitable, to increase the yield of plants in fish ponds by manuring and otherwise fertilizing the pond. He was thus enabled to largely increase the yield of fish in his ponds.

2. *The yield of the larger plants* in a lake is dependent *on the amount of shallow water.* It is only in such shallow water as occurs on the lake terrace that these plants find soil for attachment and sufficient light. A great relative shore development (Seligo '90) such as we find on the northeast shore of Lake St. Clair, therefore furnishes a large yield of water plants, while the slight shore development of the rest of the lake is unfavorable. The absence of a terrace is also unfavorable. Although there is no terrace in Lake St. Clair, yet the shallowness of the whole lake compensates for this, since it gives an opportunity for a more extended growth of *Chara* than could find place on the lakeward border of a narrow terrace.

3. *The transparency of the water.* Aquatic plants, like others, are dependent on the light for their growth. If the water is transparent so that it admits the light to considerable depth, such plants as the Charas which grow upon the bottom are able to exist in deeper water and thus to cover a larger area of the lake bottom. The minute floating plants are also able to exist at greater depths and consequently in greater numbers over the whole lake. The turbidity of the water of Lake St. Clair, due to the fine soil of the shore and bottom, is thus a factor unfavorable to the growth of aquatic plants. This is, however, compensated for, as already pointed out, by the unusual shallowness of the lake—which permits light to reach all parts of the bottom in sufficient amount to support an abundant growth of *Chara.*

We find, then, that the greater development of the northwest shore along the delta of the St. Clair river gives support to an abundant littoral vegetation, while the lesser shore development of the remainder of the lake *yields support to* a very scanty littoral vegetation. The shallowness of the lake favors the bottom vegetation and results in an abundant bed of *Chara*, while the turbidity of the water is one element in resisting the development of the minute floating plants. It would seem to me that the great development of the bottom vegetation more than compensates for the poor development of minute floating plants and of littoral plants along much of the shore. *The total yield of the lake in plants is therefore probably greater than would be the case in a deeper lake of the same size, with more transparent water and greater shore development.* It should be understood, however, that this statement is not the result of any accurate measurements.

The Animals: Representatives of the following groups of animals are found in the lake.

Protozoa.
Cœlenterata (Sponges, Hydroids).
Turbellaria (Non-parasitic, fresh water, flat worms).
Trematodes }
Cestodes } Parasitic flat worms.
Nematodes (Thread worms, some free, others parasitic).
Hirudinei (Leeches).
Oligochæta (Earth worms and related forms).
Bryozoa ("Moss" animals).
Rotatoria ("Wheel" animalcules).
Crustacea.
Acarina (Hydrachnidæ or water mites and Oribatidae).
Insecta.
Mollusca (Snails and mussels).
Vertebrata (Birds, turtles, Amphibia and fishes).

The following summaries indicate briefly what is known with regard to each group. A report on the Rotatoria has been issued as Bulletin No. 3 of the Michigan Fish Commission. Reports on other groups are expected to be issued as soon as ready. Preliminary reports and such others as are not sufficiently extended to warrant their publication as separate bulletins, are appended to this paper.

1. The Protozoa: From the notes of Mr. Frank Smith, which are appended to this report, it appears that he recorded altogether thirty-two species. Of these, ten were taken at a distance from the shore at the surface with a tow net. Six were taken in the same localities at the bottom with the tow net and dredge. Of these six, four were found also at the surface so that but two species were at or on the bottom which do not also occur at the surface. Of these two, one, a *Vorticella*, is a fixed form. Practically, therefore, the protozoan fauna of the bottom at a distance from shore does not present any species, with the exception of *Amphileptus gigas*, which do not occur also at the top.

Of the ten species occurring at the surface—the *Difflugia globulosa* was found regularly and apparently belonged at the surface as much as at the bottom. The *Arcella*, of which only empty shells occurred, ought, perhaps, to be excluded from the list. *Actinophrys* was not found elsewhere than at the surface. The *Vorticella* was attached to other forms (passively limnetic) while the *Stentor* was doubtless a wanderer from the bottom. *If we exclude Arcella, Actinophrys*, and *Stentor*, there are left seven species which are undoubtedly pelagic in this lake in midsummer, and it is possible that *Actinophrys* should be added to this class.

The list of Protozoa occurring in the surface and bottom collections is doubtless nearly or quite complete, since the observations were many times repeated without revealing additional forms. During July and August Zacharias, (94) records 13 forms as pelagic in Plöner See. Of these, five, (2 species of *Dinobryon, Peridinium, Ceratium, Codonella*) are the same species observed by Zacharias or closely related. The other species observed by Zacharias were not reported from Lake St. Clair. Thus, evidently *the number of pelagic (limnetic) species in Lake St. Clair at this season is relatively small.* As this is the season at which this portion of the pelagic fauna reaches its highest development in Plöner See, it is not likely that a greater number of species occurs in Lake St. Clair at any other season.

In addition to the twelve species thus occurring twenty species are reported from shallow water among algæ. Further observation would doubtless have greatly extended this list.

2. Cœlenterata.

a. **The Sponges:** A fresh water sponge (the species could not be determined owing to the absence of gemmules) occurs frequently attached to the floating logs within the "boom" of the store mill at New Baltimore. Sponges (a species of *Ephydatia*) attached to the bottom were also occasionally brought up in considerable quantities by the dredge. They do not occur usually nor abundantly on the lake bottom.

b. **Hydras:** Both *Hydra viridis* and *Hydra grisea* are reported commonly attached to the vegetation and were not infrequently taken in the tow net, where their presence was no doubt accidental.

3. Worms.

a. **Turbellaria** (non-parasitic flat worms): The collection of these worms is now being studied by Dr. Woodworth, but no detailed report can be given at this time.

b. **Nemathelminthes** (thread worms, hair snakes, Acanthocephala): Free nematodes were frequently encountered, but the species remain to be identified. The parasitic Nemathelminthes are mentioned in Appendix III.

c. **Hirudinei** (Leeches): Twelve vials have been sent to Dr. R. Blanchard for identification, but his report has not yet reached me.

d. **Oligochaeta** (Earthworms and related forms): These have been sent to Dr. Gustav Eisen, but his final report is not yet received. He reports in a preliminary way "8 or 9 species principally belonging to purely fresh water forms." "It is safe to say that most of these species are new to science."

e. **Parasitic Worms** (Nematodes, Trematodes, Cestodes). For an account of these, and for further details concerning the other worms, see *Appendix III on the worms.*

f. **The Rotatoria:** One hundred and ten species of the Rotatoria have been identified from Lake St. Clair. Twenty may be distinguished as pelagic (or limnetic), the rest as littoral or bottom forms. As compared with the list of eighteen pelagic species given by Zacharias (94) ten pelagic forms are found both here and in Plöner See; ten species found in Lake St. Clair are not reported from the European lake, while eight of the species listed by Zacharias have not been observed here.

In addition to the pelagic forms ninety species of distinctively littoral or bottom Rotatoria have been observed in Lake St. Clair. Zacharias (94) reports in Plöner See but twenty-four in addition to the pelagic forms. Probably the littoral Rotatoria of that lake have not been specially investigated.

Five species from Lake St. Clair have been described as new to science.

A complete list of the Rotatoria observed in Lake St. Clair and in some of the inland lakes of Michigan, with more extended notes as to distribution and other biological data, as well as descriptions of the new forms, is given in the special report on the Rotatoria (Bulletin of the Michigan Fish Commission No. 3).

g. **Bryozoa:** A single species was found in small quantities on the aquatic plants in Anchor Bay. We did not find any Bryozoan occurring in great masses.

4. **Crustacea:** The Crustacea of the lake belong, as elsewhere in fresh water, to the groups Cladocera, Ostracoda, Copepoda, Amphipoda, Isopoda, and Astacidæ. Those belonging to the first three groups are minute and serve largely as food for young fish (Forbes). Those of the last three groups are larger forms living on the bottom and among the plants and entering to a considerable extent (especially the crayfish) into the food of adult fishes.

a. **Cladocera:** In an appendix to this paper is given a report on the Cladocera by Prof. E. A. Birge. From this I extract the following: "Twenty-two species are represented in the collection. This probably includes all the pelagic and bottom forms present at this season, but doubtless more extended collections in the littoral vegetation and on the delta of the St. Clair river would greatly extend the list of littoral forms." Nevertheless the list contains two more species than reported by Zacharias (94) from Plöner See. The lake is characterized by the abundance of *Sida crystallina* and *Monospilus tenuirostris* and by the constant presence of *Bosmina longispina* and the absence of all other species of *Bosmina*. I wish to call particular attention to the almost constant presence of *Chydorus sphæricus* O. F. M. in the material taken in the vertical net. This species which is thus pelagic throughout the lake is represented by individuals which are smaller than usual but otherwise not peculiar.

b. **Copepoda:** The collection of Copepoda is in the hands of Prof. C. Dwight Marsh, who is at work upon a report which will be published as a bulletin of the Michigan Fish Commission. He sends me the following list of species found in our collection from Lake St. Clair, the Detroit river and Lake Erie.

From Lake St. Clair:

Diaptomus sicilis Forbes.
“ *Ashlandi* Marsh
“ *minutus* Lillj.
“ *oregonensis* Lillj.
Epischura lacustris Forbes.
Limnocalanus macrurus Sars.
Cyclops brevispinosus Herrick.
“ *pulchellus* Koch.
“ *parcus* Herrick.
“ *ater* Herrick.
“ *albidus* Jur.
“ *fluviatilis* Herrick.
“ *serrulatus* Fischer.
“ *bicolor* Sars.

From the Detroit river:

Diaptomus sicilis Forbes.
“ *Ashlandi* Marsh.
“ *minutus* Lillj.
Limnocalanus macrurus Sars.
Cyclops brevispinosus Herrick.
Cyclops pulchellus Koch.

From Lake Erie:

Diaptomus oregonensis Lillj.
Epischura lacustris Forbes.
Cyclops brevispinosus Herrick.
“ *Leuckarti* Sars.
“ *fluviatilis* Herrick.

Thus the preliminary examination shows in Lake St. Clair fifteen species of free swimming Copepoda. Among these the *Cyclops ater* of Herrick is noteworthy. It occurs in considerable numbers on the bottom. The species was insufficiently described by Herrick and has not, to the knowledge of the writer, been recorded by any subsequent observer. A detailed description prepared by the writer from living specimens will appear with figures in the forthcoming report of Prof. Marsh. One interesting fact concerning this species may here be recorded. In color, form, size and movements it closely resembles a species of *Arrenurus* (one of the water mites) with which it is constantly associated. This resemblance is so close that it requires long practice to distinguish the two forms. This is possibly a case of “protective mimicry.”

To the fifteen free living Copepoda must be added two other species of that group. 1. A species of *Ergasilus*. This semiparasitic form was frequently found free in the bottom tow, but never attached. It appears to be a new species. 2. A parasitic form probably one of the Lernæopoda, a single specimen of which was found attached to *Acipenser*. There are thus recorded seventeen species of Copepoda. The Plöner See list contains thirteen.

c. **The Ostracoda** occur in abundance over the whole lake among the plants of the bottom and shore. The species have not been determined.

d. **The Amphipoda** (fresh water shrimps) are represented by numerous individuals in the vegetation of the shore and bottom. The well known *Hyalella dentata* Smith occurs everywhere. The collection has not been studied *so that it is* not known whether other species are present.

e. **The Isopoda** are represented by large numbers of the genus *Asellus* which occur in the vegetation of bottom and shore. The species has not been determined. There may be several species or even genera.

f. **The Astacidæ** (crayfishes) are very abundant in certain parts of the lake in the neighborhood of the St. Clair Flats. We did not take them elsewhere, though the stomachs of fish taken in other parts of the lake often contained very many of them. We found only *Cambarus propinquus* Girard, through other species may be present in the lake. It forms an important element of the food of certain species of fish (e. g. *Amia*). A new species of *Distoma* (*D. opacum*) encysted in this crayfish has been recently described by Dr. Ward in the Proceedings of the American Microscopical Society, 1893, where some points in its life history are also given.

5. **Hydrachnidæ.** The water mites of the lake are being worked up by Dr. R. H. Wolcott, and it is intended to issue a special report upon them. A very brief summary of the facts collected concerning the members of this group is given in Appendix IV. From this it appears that eighteen genera containing thirty-six species have been recognized, of which probably three genera and a score of species are hitherto undescribed. The species are widely distributed over the lake. In addition to the water mites proper, Dr. Wolcott records the presence of a species of horny mites (family Oribatidæ).

6. **Insecta:** An account of these is given in Appendix IV. The list shows seventy-two species, but as these (most of them immature forms) can be identified only by rearing them, they have remained for the most part undetermined. The number of individuals in the lake is very great, owing doubtless to the broad expanse of bottom vegetation, and they form a most important element of the food of the fishes.

7. **Mollusca:** Snails are abundant on the vegetation of the bottom and shore, while mussels probably occur over nearly the whole lake bottom. Appendix I contains a list of the species and should be consulted for details. The identifications are most of them due to the kindness of Mr. Bryant Walker, of Detroit. From this it appears that twenty-three species of Gastropoda (snails) occur. It is not likely that any have been overlooked. They form an important element of the food of fishes. Of the Lamellibranchs (mussels) twenty-two species are reported—fifteen of the genus *Unio*, two of *Margaritina*, three of *Anodonta*, and two of *Sphaerium*. Although spread over a large area of the lake bottom, these forms are much more abundant in certain localities than in others. The *Sphaeria* are small, and important as fish food. The other Lamellibranchs are large, protected by a heavy shell and have the habit of living partly imbedded in the bottom. They do not therefore in their mature condition appear to possess any importance as fish food. In their immature condition they may enter into the food of fishes, but I do not know that this has been observed. Our list thus contains forty-five Mollusca. The Plöner See list, already so often quoted, contains twenty-one. Owing to the often ill-defined limits of our species of Mollusca, the number of them contained in any collection necessarily varies with the point of view and experience of the specialist to whom they are submitted. Personal knowledge of Mr.

Walker's methods enables the writer to say that he has probably not recognized too many species, he is rather more likely to have recognized too few.

8. **Vertebrata:** Many gulls and terns frequent the lake. Two or three species of turtles are also present—*Chelydra serpentina* (L.), *Chrysemys marginata* (Ag.)—but turtles are not abundant and were never seen in deep water nor taken in the gill nets. Many frogs also frequent the St. Clair Flats and other similar portions of the lake shore. On the whole, however the shore development is not favorable to either Amphibia or Reptilia.

The following species of fish were taken in the lake. (The names are from Jordan's Manual of the Vertebrata, 5th Edition, 1890):

Acipenser rubicundus Le Sueur, Lake sturgeon.
Amia calva L., dog fish.
Lepidosteus osseus (L.) Ag., Gar pike.
Ambloplites rupestris (Raf.), Rock bass.
Ameiurus natalis (Le Sueur), Yellow cat.
Ictalurus punctatus (Raf.), White cat.
Aplodinotus grunniens (Raf.), Sheepshead.
Catostomus teres (Mitch.), Common sucker.
Moxostoma aureolum (Le Sueur), Lake red horse.
Cyprinus carpio L., Carp (introduced).
Esox lucius L., Pike.
Esox masquinongy (Mitch.), Muskallunge.
Hiodon tergisus Le Sueur, Moon eye.
Lepomis gibbosus (L.), Pumpkin seed.
Micropterus dolomieu (Lacép.), Small-mouthed black bass.
Perca flavescens (Mitch.), Yellow perch.
Roccus chrysops (Raf.), White bass.
Stizostedion canadense (C. H. Smith), Sauger.
Stizostedion vitreum (Mitch.), Wall-eyed pike.

To these nineteen easily recognized species must be added at least two species of minnows not yet determined and a small Teleost, probably an *Etheostoma*, found feeding voraciously on the Crustacea of the bottom vegetation. The whitefish, *Coregonus clupeiformis* (Mitch.), also enters the lake in November. There are thus at least twenty-two species (three Ganoids, nineteen Teleosts) in the lake in the summer and one more in November—twenty-three species in all. We found no fish eggs, probably owing to the time of year. We found frequently in the surface tow a small and very delicate larva of a bony fish—but were unable to rear it or to determine the species.

The contents of 113 fish stomachs belonging to sixteen species were collected and are undergoing examination. It is expected that a bulletin will be issued on this subject when the work is completed. A collection of 291 stomachs from fishes of the inland lakes is also being examined.

A summary of the animals and plants of the lake is therefore as follows:

I. PLANTS.				
Phanerogams			47	
Characeæ			5	
Algæ (exclusive of Diatoms and Desmids) (fixed 13, free 14)		27		
Diatoms		15		
Desmids		64	–106	— 158
II. ANIMALS.				
Protozoa			32	
Coelentera			3	
Turbellaria, at least			5–6	
Nemertini			1	
Trematoda, probably			30	
Cestoda, probably			25	
Nemathelminthes, probably			20	
Hirudinei, probably			10	
Oligochæta, probably			8	
Bryozoa			1	
Rotatoria			110	
Crustacea	Cladocera	22		
	Copepoda	17		
	Ostracoda	1		
	Amphipoda	1		
	Isopoda	1		
	Astacidæ	1	—43	
Acarina			37	
Insecta			72	
Mollusca			45	
Vertebrata (fishes)			23	— 465
				623

A mere catalogue of the animals and plants of the lake, such as has just been given, is not in itself of great interest. Such a collection of facts becomes of interest and of value in so far as it has a meaning. To understand how a certain group of animals or plants comes to be in the lake, how it maintains itself there, and what changes are produced in it by the interaction between it and its surroundings—these are the things of interest. To know such things concerning any fish is to be able to act intelligently in any matter concerning that fish; not to know them is to act in the dark and to risk every chance of failure.

For the most part these things are still to be learned, but it has seemed to me worth while to make here a somewhat broad statement of the relationships existing between the animals and plants in such a lake as St. Clair.

In the first place it is to be said that all the plants draw their nourishment from the water. They are floating in a nutrient fluid. Even in the case of plants rooted to the bottom, the roots serve largely or wholly as anchoring organs and not as organs for absorption. The amount of nutrient substances in solution in the water is then, as already pointed out, probably the most important element in determing the yield of the lake in plants. The amount of such substances is in its turn dependent upon the form of the lake, its shore development and upon the character and extent of the lake basin.

In the second place all animals are dependent upon the plants for their food. The may be directly dependent, using plants exclusively as food, or they may be indirectly dependent, using as food other animals, which are in their turn dependent on plants.

I bring together here a few statements as to the food relations of some fresh- water animals taken largely from Seligo (90).

Insect Larvæ: *Chironomus larvæ* are common on the bottom; there is one, the large red Chironomus larva, very common on the bottom in deep water, which is eaten by certain fish. The larva itself feeds upon minute plants *(Protococcus,* Diatoms) and upon the remains of decayed plants. It is eaten by carnivorous insect larvæ of the following groups: Ephemeridæ; Perlidæ; Sialadæ; Libellulidæ; Phryganid larvæ without tubes; water beetles; and also by Planarian worms.

Phryganid larvæ with tubes (Caddis-fly larvæ) feed mostly on living plants, but have been seen eating dead fish and snails. They are eaten by fish and crayfish.

Bugs: *Nepa* is a plant eater; *Notonecta* and *Naucoris* attack fish larvæ.

Hydrachnids are for the most part carnivorous.

Crustacea: The *Crayfishcs* eat almost any vegetable or animal matter whether dead or living. They are largely eaten by fish.

Amphipoda (Gammarus) frequently eat Copepoda *(Cyclops).* They are eaten by fish.

Asellus, lives on the organic constituents of the bottom ooze.

The *Copepoda* live mostly on unicellular algæ (diatoms and Chroococcaceæ). DeGuerne and Richard make such a statement for Calanidæ.

The *Cladocera* live also principally on unicellular algæ. (Apstein 92, makes the statement for Daphnidæ.) Both Copepoda and Cladocera ,are taken as food by most fish larvæ (fry). The Cisco or herring of our inland lakes also feeds upon the Cladocera and Copepoda of the plankton, I have observed this in Wabasis Lake, Kent Co., Mich. Probably the herring of the Great Lakes has the same habit. The herring of the Great Lakes in its turn is stated by fishermen to form a large part of the food of the lake trout.

Mollusca: *Snails* eat the living tissues of higher plants. They are in turn eaten by leeches *(Nephelis, Clepsine).* These leeches are in turn food for fishes.

Lamellibranchs (Anodonta, Cyclas, Pisidium): live on the organic constituents of the bottom water and bottom ooze.

Worms: Tubifex lives on the organic constituents of the bottom ooze. No doubt this list could be largely extended by a careful examination of the literature, but it is sufficient for the purpose.

In the following table (p. 24) I have attempted to express a part of the imperfectly known relationships existing between the various groups of plants and the invertebrate animals on the one hand and the fishes on the other hand. I do not know that any of our native fish live directly upon plants.

Dead Matter.	**Plants.**		**Intermediate Groups of Animals.**		**Fishes.**
In solution in water is food for	I.—**Higher Plants.** **Characeæ** and **Phanerogams.**	Fresh, eaten by ..	Gasteropods	Eaten by	**Whitefish; Pumpkin Seeds.**
				Eaten by leeches .... Eaten by	**Whitefish.**
			Phryganid larvæ with tubes ...	Eaten by	**Many fish.**
				Eaten by crayfishes ..... Eaten by	**Bass, Perch and many others.**
		Decayed, eaten by	Chironomus Larvæ ... Eaten by .	Larvæ of — Ephemeridæ .... Perlidæ .... Sialadæ .... Libellulidæ .... Phryganidæ (without tubes) . Coleoptera .... Planarian worms .... All of these are eaten by	**Fish.**
	II.—**Algæ.**	fixed, floating and in the bottom ooze are eaten by	**Daphnidæ** (and Copepoda)	Very important food for..............	**Fish larvæ** of many kinds.
				Eaten by **Herring** (of the lakes) eaten by ..	**Lake Trout.**
			Copepoda (Calanidæ) eaten by	**Leptodora,** very important food for.	**Fish larvæ** of many kinds.
				Rotifera (Asplanchna).	
				Gammaridæ, eaten by	**Brook Trout.**
				Hydrachnids.	
				Hemiptera (bugs).	
			Many Protozoa.		
			Lamellibranchs (Anodonta, Sphærium, etc.), eaten by		**Whitefish** and others.
			Bryozoa.		
			Asellus ... Tubifex ...	Are eaten by	**Fishes.**

It is quite impossible to understand a fish so as to know how to deal with it intelligently without knowing its food. We are thus led back step by step until we come to the plants and from them we go to the chemistry of the water and from this to the character of the lake basin and its geological history. From the merest practical point of view I am unable to see where we can stop in our investigation short of a *complete knowledge of all the chain of relations* which extend from soil of the lake basin upward to the mature fish.

QUANTITATIVE PLANKTON WORK.

After six weeks spent in the determination of the lake fauna and flora the attention of the laboratory staff was turned in large part toward the question of the distribution of these forms and toward measurements of the total volume of minute animals and plants found in a given volume of water. For this purpose twenty-one stations were selected. Fifteen of these were in Lake St. Clair. Since the time was limited these fifteen stations were located on the American half of the lake and were more numerous in the neighborhood of the fishing-grounds. Their distribution is shown on the accompanying chart. It will be noticed that while they are not scattered over the entire lake, they represent all the conditions of bottom, shore, and depth that are to be found in the lake. Any conclusions concerning them probably hold for the entire lake. Three stations were located near the head of the Detroit river, while for the purpose of comparison three others were located in the western end of Lake Erie.

At each station the various forms of nets were used and the collections made were preserved. Their study will determine the distribution of the animals and plants. In so far as this distribution has been determined it appears in the special reports appended to this article and in the bulletins already referred to.

An attempt was also made to measure at each station the quantity of minute animals and plants floating free in the water under each square metre of surface.* No methods have yet been devised for determining the quantity of the animals or plants that are attached to the bottom or that live upon it. Measurements are therefore to be made only upon those forms that are found floating free in the water. There is reason to believe that whitefish fry (and probably the fry of many other young fish) feed for a time upon the minute animals (Crustacea) floating free in the water (Forbes 83). Thus it becomes at once a question of great practical importance to know where these crustacea are to be found in greatest numbers, so that the whitefish fry may be planted in such localities. Such measurements have also a very high scientific interest.

Quantitive determinations of the living forms in the water have not been previously undertaken in this country and its methods are almost unknown among us. They have been carried out on a large scale by Prof. Victor Hensen of the University of Kiel. Hensen has examined the

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*The name *plankton* has been given by Hensen to all those animals and plants which are found floating free in the water, and subjected to the action of waves, currents or tides. Thus adult fish do not belong to the plankton, since they are able to move about independently of waves or currents. Fish eggs and young fish fry are reckoned as a part of the plankton. The constitution of the plankton varies, since occasionally forms which belong on the shore or bottom wander into the free water and become a part of the plankton.

waters of the North Sea and more recently those of the Atlantic Ocean and has perfected very ingenious apparatus for the purpose. Apstein, a pupil of Hensen, has adapted this apparatus for use in fresh water and has made a careful study of several fresh water lakes in the neighborhood of Kiel.

As it was found necessary for work in the Great Lakes to modify the apparatus and methods used by Hensen and Apstein, I give here a somewhat detailed account of our procedure.

The net used for this purpose is shown in the accompanying plate (Pl. figs. 1 and 2.) The upper part of the net consists of a truncated canvas cone (cn.) supported on an iron framework. This cone is about 40 cm. high; the smaller end has a diameter of 40 cm. and the larger end a diameter of 60 cm. It is impervious to water and serves two purposes. When the net is let to the bottom it prevents the mud which may be upon the bottom from getting into the net and while the net is being drawn up it prevents its contents from spilling over the edge, a thing which might otherwise happen with a boat pitching in a heavy sea.

From the iron ring which supports the broader end of the cone depends the net proper (nt). The net is a cone with a slant height of about 100 cm. It consists of No. 20 silk bolting cloth, a very strong fabric which contains many very small openings nearly uniform in size.* This cloth or gauze has the further advantage of not undergoing changes in water and of not yielding any lint to contaminate the plankton. The outside of the gauze net is protected by a twine net of inch mesh which serves to take up the strain on the gauze net when it is drawn through the water. The lower end of the gauze net does not run to a point, but is truncated and attached to a flat metal ring. To this ring there is attached a bucket (bk.) which is shown separated from the net in fig. 2, A. In order that the weight of the bucket may not be borne by the net six stout cords (crd.) run from the upper net ring to the lower net ring and are made of such length that they support the weight of the bucket. The bucket is essentially a metal cylinder about 6 cm. in diameter inside and 6 cm. deep. It is supported on three legs. At the top it is arranged to be attached to the bottom ring of the net by means of three binding screws. The sides of the bucket are cut away as much as possible so as to leave only six narrow strips of metal and the windows thus formed are filled with gauze like that of the net. The bottom of the bucket is conical and has at its middle an outlet tube, closed by an accurately fitted plug which may be removed from the inside. This plug is shown separately at fig. 2 B.

The whole net is suspended by means of three cords from a support consisting of three radiating arms. At the junction of the three arms is a strong iron ring from which runs a rope by means of which the net is drawn up. The rope is divided into feet or fractions of a metre so that one may read off the depth to which the net descends. By holding in the hand the triradiate support from which the net hangs the latter may be kept from twisting on the supporting rope.

In working a spar is lashed to the upper deck of the steamer, so that its end extends about four feet beyond the side of the vessel. To the end of the spar is lashed a pulley through which the net rope runs. The net is then allowed to sink. In going down it takes in no water except that which is filtered through the gauze. It is sometimes let to the bottom and

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*See appendix v.

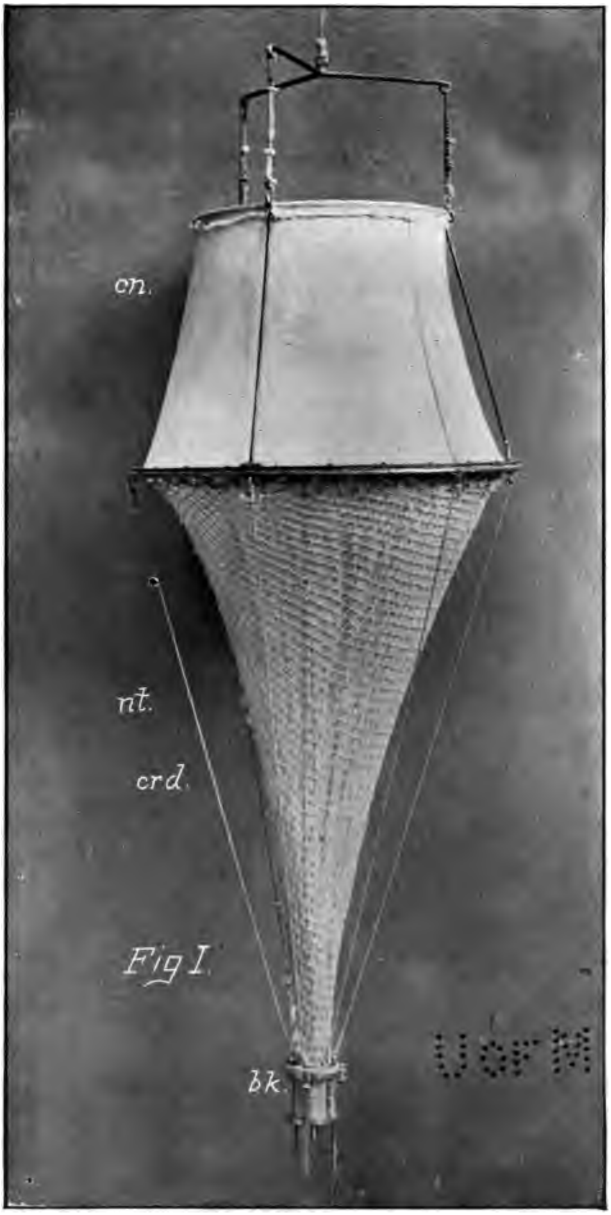
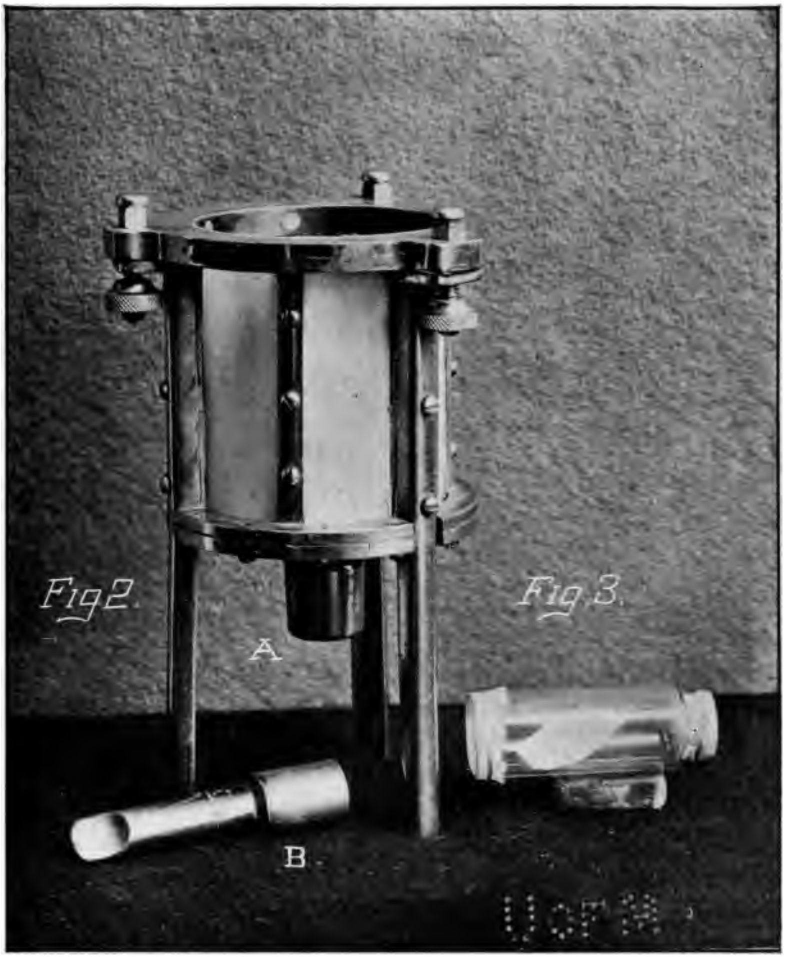


Fig I.

U of M

PLATE I.



UofM

PLATE II.

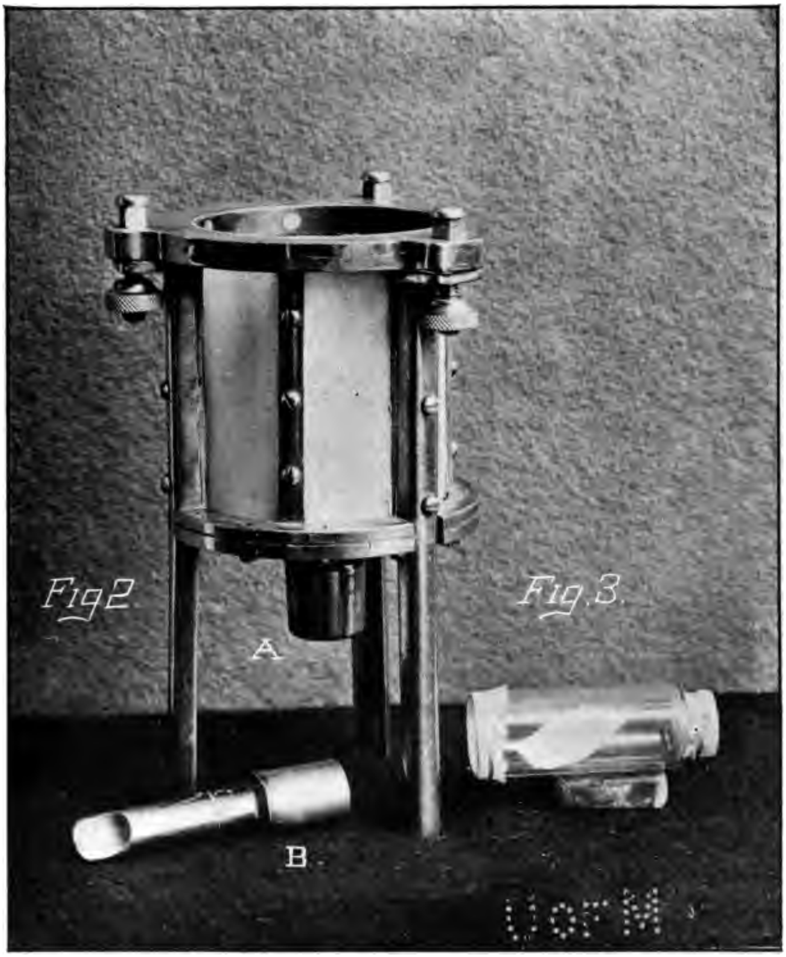


PLATE II.

M40U

sometimes to a depth of only 1½, 3, 4, or 6 metres. It is then drawn up by hauling in the rope hand over hand. The net is always hauled up by the same person, while another person makes note of the number of seconds between the time it leaves the bottom and the time the top of the canvas cone reaches the surface. From this time the velocity of the net is determined. The net has thus strained a vertical column of water. The base of this column has an area equal to the area of the net opening, while the height of the column is the distance through which the net was drawn. The net is now drawn out of the water and allowed to hang at the end of the spar while the water drains out of it. At the same time a stream of water from a hose is turned onto the outside of the net. This water passes through the net gauze to the inside of the net. It is thus strained by the gauze so that it does not add anything to the material captured in the net. This water washes down all the plankton into the bucket beneath.

After the water has partly drained out of the bucket the binding screws are loosened and the bucket is removed and taken into the cabin. Here nearly all the water is allowed to drain out through the gauze sides of the bucket and the plankton adhering to the inside is washed down into the conical bottom by means of a stream of filtered water from a wash bottle. All the material taken in the net is thus collected into the conical bottom of the bucket. A small glass beaker is then placed beneath the tube in the bottom of the bucket, the plug is removed and the plankton falls into the beaker. The inside of the bucket and the plug are then rinsed several times in filtered water, and the rinsing water is added to the material in the beaker. The small quantities of material obtained necessitates great care in handling it lest some of it be lost. The substitution of a plug in the bottom of the bucket for the stopcock used by Apstein is believed to be an advantage in that it allows the inside of the tube to be rinsed with greater thoroughness.

The small quantity of material now in the beaker contains very minute forms. If this material be turned into a bottle of some fixing or killing fluid, and if this fluid be afterward poured off and alcohol substituted for it, some part of the material is likely to be poured off and lost. After much experimenting we finally hit upon the following device for preserving the material.

A short 6-drachm homeopathic vial has its bottom removed and edges annealed. The bottom is then closed by tying over it with fine silk thread a piece of the No. 20 gauze such as is used for the net. The contents of the beaker are poured into this tube, and by a gentle tapping of the tube with the forefinger of one hand while holding it between the thumb and forefinger of the other hand, the water is made to filter very rapidly through the gauze bottom leaving the plankton in the tube. Before all the water has filtered away a label is placed in the tube and the open end is closed by tying over it a piece of the gauze. The tube (see Fig. 3) is then placed with other tubes in a large bottle of fixing fluid (we use alternately Flemming's solution and Kleinenberg's picro-sulphuric acid). The tube is then passed through successive grades of alcohol (preceded by water in the case of the use of Flemming's solution) and is finally preserved in 82 per cent alcohol. In passing the tube from one fluid to another it may be emptied of its fluid by forcing the air into it by means of a pipette held against the gauze at either end. When the tube emptied of its fluid is placed *in the next fluid* it may be filled by immersing it in the fluid and *removing with a pipette* the air previously forced in. The material does not pass through the gauze used in closing the ends of the tube. This method prevents the loss of plankton in the manipulation and it also saves much time and enables one to pack many tubes of plankton in a single large vessel.

When the plankton has been preserved in the tubes they are taken to the laboratory in order to continue the work. Here the contents of each plankton tube are measured in the following manner: The gauze is removed from one end of a tube and carefully rinsed free from any adhering plankton. The alcohol used in rinsing is placed in a beaker and the contents of the tube poured into the beaker. The tube and the other gauze are thoroughly rinsed and the rinsings placed in the beaker. The contents of the beaker are now turned into a tube graduated to tenths of a cubic centimetre. This tube is allowed to stand twenty-four hours in order that the lighter constituents of the plankton may settle, and the volume is then read off and recorded.

The area of the opening of our net (the upper end of the canvas cone) is 1,237.86 square centimetres. If the net has been drawn a distance of one metre (100 centimetres[1]) it has passed through a column of water containing 1,237.86 x 100, or 123,786 cubic centimetres of water. If the net actually strained the whole of this column of water, the plankton contained in the tube would be the amount of plankton contained in 123,786 cubic centimetres of water—or if the net has been drawn from the bottom and the water is but one metre deep it would be the amount of water contained under 1,237.86 square centimetres of the surface. The net does not, however, strain the whole of the column of water through which it passes. A part of this water is strained, while another part is forced aside by the resistance of the net. The net may thus strain only one-half of the column of water through which it passes and the plankton taken would then be that contained in one-half the column of water traversed by the net. In order to get the volume of plankton in the whole column of water traversed by the net, it would be necessary in this case to multiply the volume taken by 2. This number is called the coefficient of the net. The coefficient varies with the velocity of the net. The method of determining the coefficient of such nets has been very ingeniously worked out by Hensen (87) and is discussed in an appendix of this paper, in which there is given a table showing the coefficient of our net at different velocities and the total correction to be applied in using it. The coefficient of our net for velocities between 50 and 75 centimetres per second, varies from about 2½ to about 2.

The volume of plankton taken multiplied by the net coefficient gives the volume under 1,237.86 square centimetres of the surface, reckoning from the depth from which the net is drawn. In order to make comparisons with the work of other observers it is customary to state the results in terms of the volume of plankton under one square metre of the surface. The area of our net is about one-eighth of a square metre, so that the volume of plankton under one square metre is obtained by multiplying by 8 (more accurately by 8.08). Thus the volume of plankton taken multiplied by a number (about 2) representing the coefficient of the net, and also by another number (about 8) gives the total volume of plankton under one square meter of surface. It is more convenient to make the two corrections at one time and to multiply the volume of plankton taken by a number (about 16) which represents the *total correction* to be made.

The following table shows the results obtained by us:

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[1] *A centimetre is .3936 of an inch linear.* A meter is 100 centimetres, or 39.36 inches linear.

Schedule of the Hauls of the Plankton Net.

Date, 1893.			Number of haul.	Depth of water in metres.	Depth of haul in metres.	Velocity of net in metres per second.	Temperature of water in degrees centigrade.		Temperature of air in degrees centigrade.	Wind, strength and direction.	Current.	Sky.	Condition of water.	Volume taken in cubic centimetres.	Volume under one sq. metre of surface.	Volume per cubic metre of water.
Mo.	Day.	Hour.					Top.	Bottom.								
IX	7	11:15 A. M.	I	4,11	3,71	,53	18,1	—	22,8	N W b N	—	Hazy and cloudy	Slightly rough	,92	18,44	4,97
		11:30	I^2	4,11	2,50	,65	18,1	—	22,8	N W b N	—	(Clear and hazy with slight clouds)	Slightly rough	,48	8,45	3,38
		12:10 P. M.	I^3	4,11	1,50	((,30) ,65)	18,1	—	22,8	N W b N	—	Clear and hazy	Slightly rougher than I^2	,47	8,28	5,52
		2:30	II Q	5,41	5,00	,71	18,1	—	25,6	N W b N	—	Clear, slightly hazy	Slightly rough	,43	7,19	1,44
		2:30	II	5,41	5,00	,71	18,1	—	25,5	N W b N	—	Clear and hazy	Slightly rough	,80	13,38	2,68
		3	II^2	5,41	3,00	(,71)	18,1	—	25,6	N W b N	—	Clear and hazy	Slightly rough	,71	11,88	3,96
		3:30	II^3	5,41	1,50	,61	18,1	17,7	25,6	N W b N	—	Sunny and hazy	Slightly rough	,57	10,32	6,88
	8	11:10 A. M.	III Q	5,94	5,54	,69	17,2	17,2	19,2	N E 1	—	Cloudy	Swell and slight waves	,90	15,27	2,76
		11:10	III	5,94	5,54	,69	17,2	17,2	19,2	N E 1	—	Cloudy	Swell and slight waves	1,27	21,55	3,89
		11:45	III^2	5,94	4,50	,70	17,2	17,2	19,2	N E 1	—	Cloudy	Swell and slight waves	,80	13,49	2,99
		1:15 P. M.	III^3	5,94	3,00	,61	17,2	17,2	19,8	N E 2	—	Cloudy and sunny	Swell and slight waves	,98	17,74	5,91
		1:30	III^4	5,94	1,50	,61	17,2	17,2	19,8	N E 1	—	Cloudy and sunny	Swell and slight waves	,87	15,75	10,50
		3:30	IV Q	2,91	2,50	,71	18,1	17,7	19,2	N E 1	—	Cloudy	Slight waves	,30	5,02	2,01
		3:30	IV	2,91	2,50	,71	18,1	17,7	19,2	N E 1	—	Cloudy	Slight waves	,30	5,02	2,01
		3:45	IV^2	2,91	1,50	,61	18,1	17,7	19,2	N E 1	—	Cloudy	Slight waves	,19	3.44	2,29
	9	10:40 A. M.	V Q	5,66	5,26	,81	18,2	17,9	19,8	S E 1	—	Sunny, slightly cloudy	Moderate swell	,90	14,40	2,74
		10:40	V	5,66	5,26	,81	18,2	17,9	19,8	S E 1	—	Sunny, slightly cloudy	Moderate swell	1,19	19,04	3,62
		11:15	V^2	5,64	4,50	,76	18,2	17,9	19,8	S E 1	—	Sunny, slightly cloudy	Slight swell and waves	,83	13,55	3,01
		11:30	V^3	5,64	3,00	,68	18,2	17,9	19,8	S E 1	—	Sunny, slightly cloudy	Slight swell and waves	,63	10,79	3,60
		11:45	V^4	5,64	1,50	,51	18,2	17,9	19,8	S E 1	—	Sunny, slightly cloudy	Not so rough as V^3	,54	11,08	7,39
		1:15 P. M.	VI Q	5,18	4,77	,76	17,7	17,5	—	N E b N 1	—	Sunny and cloudy	Slight waves	,67	10,93	2,29
		1:15	VI	5,18	4,77	,76	17,7	17,5	—	N E b N 1	–	Sunny and cloudy	Slight waves	,90	14,69	3,08
		1:30	VI^2	5,18	3,00	,70	17,7	17,7	—	N E b N 1	—	Sunny and cloudy	Slight waves	,93	15,63	5,21
		1:30	VI^3	5,18	1,50	,61	17,7	17,5	—	N E b N 1	—	— — — — — — — — —	Slight waves	,44	7,96	5,31
		2:30	VII Q	1,52	1,17	,67	18,9	18,9	19,8	N E b N 1	1	Sunny and cloudy	Slight waves	,25	4,32	3,69
		2:30	VII	1,52	1,17	,67	18,9	18,9	19,8	N E b N 1	1	Sunny and cloudy	Slight waves	,25	4,32	3,69
	10	11:55 A. M.	VIII Q	4,85	4,44	,68	18,4	18,1	—	N 1	2	Sunny and cloudy	Moderate waves & swell	,70	11,99	2,70
		11:55	VIII	4,85	4,44	,68	18,4	18,1	—	N 1	2	Sunny and cloudy	Moderate waves & swell	,78	13,36	3,01
		12 M.	VIII^2	4,85	3,00	(,68)	18,4	18,1	25	N 1	—	Sunny and cloudy	Swell and slight waves	,64	10,96	3,65
		12:30 P. M.	VIII^3	4,85	1,50	,55	18,4	18,1	25	N 1	—	Sunny and cloudy	Dead swell	,48	9,38	6,26
		1:45	IX Q	4,69	4,28	,74	18,4	18,1	25	N 1	3	Sunny and cloudy	Slight waves	,66	10,88	2,54
		1:45	IX	4,69	4,28	,74	18,4	18,1	25	N 1	3	Sunny and cloudy	Slight waves	,62	10,22	2,39
		2:10	IX^2	4,69	3,00	,68	18,4	18,1	22,8	N 1	—	Sunny and cloudy	Moderate waves	,68	11,65	3,88
		2:30	IX^3	4,69	1,50	,61	18,4	18,1	22,8	N 1	—	Sunny and cloudy	Slight waves	,42	7,60	5,07
		3:20	X Q	1,90	1,50	,50	19,2	18,9	20,9	N 1	—	Sunny and cloudy	Slight waves	,30	6,23	4,15
		3:20 P. M.	X	1,90	1,50	,50	19,2	18,9	20,9	N 1	—	Sunny and cloudy	Slight waves	,30	6,23	4,15
	11	10:45 A. M.	XI Q	1,68	1,27	,51	18,1	17,7	20,5	N E b N 3	—	Hazy and sunny	Quiet	,76	15,60	12,28
	12	3 P. M.	XIII Q	2,62	2,21	,60	17,7	17,7	24,2	S E b E 3	—	Cloudy, weak sunlight	Moderate waves	,58	10,59	4,79
		3	XIII	2,62	2,21	,60	17,7	17,7	24,2	S E b E 3	—	Cloudy, weak sunlight	Moderate waves	,48	8,76	3,97

Schedule of the Hauls of the Plankton Net.—Continued.

Date, 1893. Mo.	Day.	Hour.	Number of haul.	Depth of water in metres.	Depth of haul in metres.	Velocity of net in metres per second.	Temperature of water in degrees centigrade. Top.	Bottom.	Temperature of air in degrees centigrade.	Wind, strength and direction.	Current.	Sky.	Condition of water.	Volume taken in cubic centimetres.	Volume under one sq. metre of surface.	Volume per cubic metre of water.
IX		3:30	XIII^2	2,62	1,50	,61	17,7	17,7	24,2	S E b E	—	Cloudy	Slight waves	,89	7,06	4,71
		4:20	XIVQ	3,30	2,89	,60	17,7	17,5	24,2	S E b E	—	Cloudy	Slight waves	,57	10,41	3,60
		4:20	XIV	3,30	2,89	,58	17,7	17,5	24,2	S E b E	—	Cloudy	Slight waves	,51	9,56	3,31
		4:45	XIV^2	3,30	1,50	,61	17,7	17,5	24,2	S E b E	—	Cloudy	Slight waves	,49	8,87	5,91
		8	XIV^n	2,62	2,21	,52	18,6	18,4	20,7	E S E 3	—	Raining	Rough	,40	8,11	3,67
		8:15	XIV^{n,2}	2,62	1,50	,36	18,6	18,4	20,7	E S E 3	—	Cloudy, very dark	Rough	,34	11,68	7,78
		9	XIV^{n,3}	2,62	,91	,40	18,6	18,4	20,7	E S E 3	—	Cloudy, very dark	Rough	,35	9,56	10,50
		9	XIV$^{n,3\,a}$	2,62	,91	,40	18,6	18,4	20,7	E S E 3	—	Cloudy, very dark	Rough	,35	9,56	10,50
		8:30 P. M.	XIV^{n,4}	2,62	,46	,46	18,6	18,4	20,7	E S E 3	—	Cloudy, very dark	Rough	,33	7,71	16,75
		8:30	XIV$^{n,4\,a}$	2,62	,46	,46	18,6	18,4	20,7	E S E 3	—	Cloudy, very dark	Rough	,22	5,14	11,17
	13	11:45 A. M.	XVQ	5,58	5,17	(,63)	18,4	18,1	21,4	E S E	—	Cloudy	Rough	,52	9,29	1,80
		11:45	XV	5,58	5,17	(,63)	18,4	18,1	21,4	E S E	—	Cloudy	Rough	,70	12,50	2,42
		12:35 P. M.	XV^2	5,58	4,50	(,63)	18,4	18,1	21,4	E S E	—	Slightly cloudy	Rough	,78	13,93	3,10
		12:55	XV^3	5,58	3,00	(,63)	18,4	18,1	21,2	E S E	—	Slightly cloudy	Rough	,56	10,00	3,33
		1:10	XV^4	5,58	1,50	(,63)	18,4	18,1	21,2	E S E	—	Slightly cloudy	Rough	,42	7,50	5,00
		2:25	XVIQ	4,95	4,55	,76	18,4	18,1	21,4	E S E	—	Cloudy	Slightly rough	,53	8,65	1,90
		1:55	XVI	4,95	4,55	,76	18,4	18,1	21,4	E S E	—	Cloudy	Slightly rough	,65	10,61	2,33
		2:15	XVI^2	4,95	3,00	,76	18,4	18,1	21,4	E S E	—	Cloudy	Slightly rough	,57	9,30	3,10
		2:35	XVI^3	4,95	1,50	,61	18,4	18,1	21,4	E S E	—	Slightly cloudy	Slightly rough	,39	7,06	4,71
	15	8 A. M.	XVIIIQ	1,68	1,27	,56	18,9	18,9	22,8	N W 1	—	Foggy	Smooth	,37	7,09	5,58
		8	XVIIIQ^a	1,68	1,27	,56	18,9	18,9	22,8	N W 1	—	Foggy	Smooth	,32	6,13	4,83
		8	XVIII	1,68	1,27	,56	18,9	18,9	22,8	N W 1	1	Foggy	Smooth	,41	7,85	6,18
	17	10:30 A. M.	XIXQ	4,78	4,37	,73	18,1	18,1	—	N W 3	—	Clear	Rough	2,43	40,24	9,21
		10:30	XIX	4,78	4,37	,73	18,1	18,1	—	N W 3	—	Clear	Rough	4,50	74,52	17,05
		11:30	XIX^2	4,78	3,00	(,78)	18,1	18,1	—	N W 3	—	Clear	Rough	3,29	54,48	18,16
		11:45	XIX^3	4,78	1,50	(,43 (,78))	18,1	18,1	—	N W 3	—	Clear	Rough	2,66	44,05	29,37
		3:15 P. M.	XX	8,84	8,43	,75	18,9	18,6	17,7	N 1	—	Hazy	Smooth	2,47	40,51	4,81
		3:15	XXQ	8,84	8,43	,75	18,9	18,6	17,7	N 1	—	Hazy	Smooth	2,50	41,00	4,86
		4	XX^2	8,84	6,00	,87	18,9	18,6	17,7	N 1	—	Hazy	Smooth	1,75	27,86	4,64
		4:15	XX^3	8,84	3,00	,51*	18,9	18,6	17,7	None	—	Hazy	Smooth	1,97	40,42	13,47
		4:30	XX^4	8,84	1,50	,43	18,9	18,6	17,7	None	—	Foggy	Smooth	1,43	36,28	24,19
		8:30	XXI	9,83	9,42	,78	—	—	—	N 3	—	Cloudy, weak moonlight	Rough	,67	10,77	1,14

* Net slipped in drawing up.

In hauls I^3 and XIX^3 the recorded velocities were 30 and 43 centimeters. These very low velocities were not only very much less than the other velocities at the same station, but they required total corrections of about 44 and 25. I have therefore corrected these velocities so as to make them equal to those immediately preceding them at the same station. The corrected velocities at these two stations appear in parentheses and the observed velocities appear just above them. The other velocities included in parentheses were estimated, not observed. It is possible that other velocities should have been corrected.

At each station, with the exception of XIV, the velocity has heen measured for one only of the two bottom hauls — the velocity of the two bottom hauls being assumed to be equal.

The hauls marked XIV^n and XIV^{na} were made at night, the former by the light of a lantern, the latter in darkness. The low velocities are perhaps due to the difficulty of observing the time interval accurately in the insufficient light. For a fuller discussion of velocities see the appendix. Haul XIQ was made among water plants and contained much that does not belong to the plankton. Hauls III Q, III, XVI Q and XVI were made near the path of the great steamers. They

The first column contains the dates, the second the arbitrary number given to each haul of the net. The Roman numerals in the second column indicate the number of the station. Two hauls were always made from the bottom, one of these distinguished by the letter "Q" is intended to be used for qualitative work. The other bottom haul is indicated by the number of the station only. The small arabic numerals affixed to the remaining station numbers serve to indicate the different hauls which do not reach the bottom, the number 2 indicating the haul made from the greatest depth. These differ from one another usually by a metre and a half.

The third column gives the depth of water and the fourth the depth from which the net was hauled. When the net is hauled from the bottom the depth from which it is hauled is reckoned from the top of the canvas cone. It equals the depth of the water minus the height of this cone. The fifth column gives the velocity of the net. The sixth, seventh, and eighth columns give the temperature of air and water. The ninth and tenth the condition of sky and water. The last three columns give in turn the volume actually taken, the volume under one square metre of surface and the volume per cubic metre of water, all expressed in cubic centimetres. The numbers in the last column are obtained by dividing the volume per square metre of surface by the depth of the haul as shown in the fourth column.

The table includes all the data recorded at the time of making the haul. I have been unable to see any effect on the distribution or amount of plankton, arising from the very slight variations in temperature, or from the variations in the condition of the sky and water. The record of these variations appears in the table for the reason that they may in the future be found to have some meaning.

An examination of the table yields the following general statements:

1. *The volume of plankton in Lake St. Clair is relatively small.* We made altogether 27 * hauls from the bottom in Lake St. Clair, two hauls being made at every station after the first.

Number of station - - -	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XIII.	XIV.	XV.	XVI.	Ave.
Volume of Plankton in cubic centimetres per cubic metre of water	4,97	1,44	2,76	2.01	2,74	2,29	3,69	2,70	2,54	4,15	4,79	3,60	1,80	1,90	3,03
	—	2,68	3,89	2,01	3,62	3,08	3,69	3,01	2,39	4,15	3,97	3,31	2,42	2,33	

The above table shows the amount of plankton per cubic metre of water for the bottom hauls at these stations—as shown in the last column of the general table. From this it appears that there is an average at this time of year of 3.03 c. c. of plankton to each cubic metre of water in the lake.

I know of no measurements of the volume of plankton in other North American lakes. In Europe we have the very careful work of Apstein. He has recently summarized the results of an examination of eleven lakes in Holstein (see Apstein 94). On the second page of this article the volume of plankton per square metre of surface is given for each of these lakes at approximately their deepest points. He divides the lakes into two groups, the plankton-rich and the plankton-poor. Dobersdorfer See is an example of the plankton-rich lakes. In September, 1892, it contained 1242

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* Haul XI^a was made among water plants and is therefore not available.

c. c. of plankton per square metre of surface at a depth of 20 metres, i. e., 62.1 c. c. per cubic metre of water. This is more than twenty times the amount contained in Lake St. Clair at the same season. Great Plöner See may be taken as an example of the plankton-poor lakes. In September it contained at a depth of 40 metres as the average of two hauls, 200 c. c. of plankton per square metre of surface. That is 5 c. c. per cubic metre of water or considerably more than is contained in Lake St. Clair. Apstein does not record observations in the month of September in any of the other lakes. The smallest haul that he records was made in Behler See in June at a depth of 40 metres and yielded 1.9 c. c. of plankton per cubic metre of water. In July this lake yielded about 3 c. c. per cubic metre of water and in September its yield would probably have been still greater. The smallest bottom haul recorded in Lake St. Clair is II^{Q} which yielded 1.44 c. c. per cubic metre of water. *It is thus evident not only that Lake St. Clair is plankton-poor, but that it contains less plankton than any other lake yet examined.* As pointed out by Apstein the plankton production of a lake does not seem to be a question of temperature simply. Thus the temperature of Lake St. Clair in September is 17° to 18° C. and this is also the temperature of most European lakes at this season. The causes of differences in plankton production are obscure but I am inclined, with Apstein, to seek them in large part in the composition of the water.

II. *The plankton is distributed over Lake St. Clair, with great uniformity.* To determine the question as to whether the the mass of organisms in a lake are, considering them as a whole, distributed uniformly over the whole area of the lake, it is desirable to make a large number of hauls of the plankton net from the bottom and in as short a space of time as possible. The ideal arrangement would be to have a large number of nets hauled at the same instant in different parts of the lake. Since this is not practicable, the next best arrangement is to haul the same net several times in one place and then to repeat this procedure at other places within as short a time as possible. We made always two bottom hauls in succession and all our work with the plankton net in Lake St. Clair was done between the 6th and 14th of September, that is, within a period of seven days. We have thus, as it seems to me, fulfilled the conditions as nearly as is possible by the use of a single net.

If local accumulations, "swarms", of the plankton are numerous it should happen that, of two hauls made at one place and at about the same time, one of the two would often include such an accumulation white the other would not*. The volumes yielded by the two hauls would thus differ widely. For purposes of comparison the differences may be best expressed by finding by what percent of itself each of the two hauls differs from the average of the two.

In the following table I have brought together the volumes per square metre of surface for the bottom hauls made at each of the Lake St. Clair stations and that at Station XVIII in the Detroit river. Following Apstein, I have found the average of the hauls made at each station and then calculated the percentage of variation of each of the hauls from this average. These percentages are given in the last column of the table.

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* It should be noted however that an accummulation of the individuals of one or more species may be present and not produce any variation in the total volume, since such accumulations of individual species may be compensated for by a corresponding absence of other species. Such accumulations of individuals could be best made evident by counting. It should be further noted that bottom hauls of the vertical net cannot detect the presence of plankton accumulations if these are formed by vertical migration from a condition of uniform distribution: since in such case all vertical columns of water of equal dimensions and extending from surfarce to bottom must contain equal volumes of plankton. For the detection by the vertical net of plankton accumulations formed by vertical migration it is necessary to compare nearly contemporary hauls which do not reach the bottom; even in *this case such accumulations may* be so located and so formed as to remain undetected.

Number of haul.	Depth.	Volumes per square metre of surface.	Average.	Percentage of difference from the average.
IIQ	5,	7,19	10,29	43,1
II	5,	13,38		23,1
IIIQ	5,54	15,27	18,41	20,6
III	5,54	21,55		14,6
IVQ	2,50	5,02	5,02	0
IV	2,50	5,02		0
VQ	5,26	14,40	16,72	16,1
V	5,26	19,04		12,2
VIQ	4,7	10,93	12,81	17,1
VI	4,7	14,69		12,8
VIIQ	1,17	4,32	3,32	0
VII	1,17	4,32		0
VIIIQ	4,44	11,99	12,68	5,7
VIII	4,44	13,36		5,1
IXQ	4,28	10,88	10,55	3,0
IX	4,28	10,22		3,3
XQ	1,50	6,23	6,23	0
X	1,50	6,23		0
XIIIQ	2,21	10,59	9,68	8,6
XIII	2,21	8,76		10,4
XIVQ	2,89	10,41	9,99	4,1
XIV	2,89	9,56		4,4
XVQ	5,17	9,29	10,895	17,3
XV	5,17	12,50		12,8
XVIQ	4,55	8,65	9,63	11,3
XVI	4,55	10,61		9,3
XVIIIQ	1,27	7,09	7,023	,9
XVIIIQa	1,27	6,13		14,6
XVIII	1,27	7,85		10,5

Excluding II^{Q} the remaining hauls show the following variations:

The variation in 11 hauls lies between 0 and 5%
" " " 4 " " " 5.1 and 10%
" " " 8 " " " 10.1 and 15%
" " " 3 " " " 15.1 and 20%
" " " 2 " " " 20.1 and 25%
Total 28

26 hauls, or 90% of 29 hauls } between 0–20%

Thus 90 per cent of the hauls show a variation of not more than 20 per cent from the average, while none of the twenty eight shows a greater variation than 25 per cent. This result agrees very well with that of Apstein (92). The opening of the net used was sufficient (1,238 square centimetres) so that if swarms had been present in any of these hauls they should have made themselves evident in the volumes. The variation of 43 per cent which appears in haul IIQ is, possibly, sufficient to be referable to a "swarm".

We have not undertaken to count the organisms in the hauls and cannot therefore say whether the number of individuals of each species shows as great uniformity of horizontal distribution as the volumes.

This lake is peculiar in the existence in it of currents produced by the large volume of water flowing through it. It may be urged that the absence of "swarms" in it is due to the existence of these currents which would have a tendency to break up these "swarms" and distribute their constituent individuals. It seems to me, however, that this objection cannot be urged and for two reasons:

1. There is almost every possible variation in velocity of current from a velocity which at the mouths of the channels may be four miles an hour to one which, in Anchor Bay and near the center of the lake, is only to be detected by the use of instruments. Yet under none of these conditions did we find "swarms", produced by horizontal migration.

2. The mechanical effect of the numerous and varying currents present in this lake would seem to me to favor the accumulation of any floating matter, as the plankton, in eddies and other similar places. Such accumulation of both floating and submerged objects is a familiar sight in rivers. In the ocean Haeckel (91) has pointed to currents as the causes of "swarms". In spite of the existence of diverse currents in Lake St. Clair, we have not found "swarms", of horizontal migration.

On the other hand, the large area of the lake, coupled with its shallowness, gives opportunity for the development of large waves, which probably agitate the water to the bottom. Such agitation doubtless favors the breaking up of "swarms" and the uniform distribution of plankton.[1]

III. *There is much more plankton in the surface stratum* of water *than in any deeper layer of equal volume.* In all of our hauls in Lake St. Clair, where the water was deep enough, we distinguished three or four strata as follows:

1. A superficial stratum from 1.5 metres to the surface.
2. An upper middle stratum from 3 metres to 1.5 metres.
3. A lower middle stratum from 4.5 metres to 3 metres.
4. A deep stratum from bottom to 4.5 metres.

In the following table I have brought together the volumes per square metre of surface made at each[2] of the stations in Lake St. Clair and at the two in Lake Erie. All volumes in this and the following tables are expressed in cubic centimetres:

Number of station - - - - -	II.	III.	V.	VI.	VIII.	IX.	XV.	XVI	XIX.	XX	Depthsat station XX.
1,5 m.—O. - - - - - - - - - - -	10,3	15,8	11,1	8,	9,4	7,6	7,5	7,1	44,1	36,3	—
3 m.—O. - - - - - - - - - - -	11,9	17,7	10,8	15,6	11,	11,7	10,	9,3	54,5	40,4	—
4,5 m.—O. - - - - - - - - - - -	10,3[3]	13,5	13,6	12,8[4]	12,7[5]	—	13,9	9,6[6]	—	27,9	6—0 m.
5,5 m. or bottom—O - - - -	—	18,4	16,7	—	—	—	10,9	—	—		
	—	—	—	—	—	—	—	—	—	40,8	8,43—0 m.

In the horizontal columns are given the volumes contained in columns of water from 1.5 metres to the surface (1.5—0), from 3 metres to the surface (3—0), from 4.5 metres to the surface (4.5—0), and from 5.5 metres, or the bottom, to the surface (5.5—0). If, now, following the method of Hensen and of Apstein, I subtract the plankton of the column 1.5—0 from that of the column 3—0, I obtain the plankton of the column 3—1.5— that is of the upper middle stratum, as above defined. Similarly, the subtraction of the plankton of column 3—0 from that of the column 4.5—0 gives that of the column 4.5—3, or that of the lower middle stratum. The subtraction of the column 4.5—0 from that of the column 5.5—0 gives the plankton of the deep stratum as above recognized.

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[1] See note on page 40.

[2] Station I is omitted because the strata at this station were not made uniform with those at the other stations.

[3, 4, 5, 6] — These hauls are from the bottom; the depths in the order named are 5, 4,77, 4,44 and *4,55 metres.*

In the following table these subtractions are carried out and the volumes for the stratum 1.5—0 are taken directly from the preceding table.

Number of station	II.	III.	V.	VI.	VIII.	IX.	XV.	XVI.	XIX.	XX.	Thickness of deep Strata Station XX.
1,5 m.—0.	10,3	15,8	11,1	8,	9,4	7,6	7,5	7,1	44,1	36,3	
3—1,5 m	1,6	1,9	—,3	7,6	1,6	4,1	2,5	2,2	10,4	4,1	
4,5—3 m.	—1,6	—4,2	2,8	—2,8	1,7	—	3,9	,3	—	—12,5	6 —3 m.
5, + —4,5 m.	—	4,9	3,1	—	—	—	—3,0	—	—	12,9	8,43—6 m.

From this table it appears: (1) That the upper stratum contains a much larger volume of plankton than any of the others. (2) That there are no constant differences between the volume contained in the upper middle, lower middle, and the deep strata as here defined. Thus in V the result for the stratum 3—1.5 is negative, and the same result appears in the stratum 4.5—3 under III and VI. The numbers representing the volumes in each of the lower strata also vary greatly. At some stations the figures indicate an increase of volume as we approach the bottom, in others a decrease.*

In order to analyze the difference which exists between the superficial stratum and the sum of those beneath, I have brought together in the following table the volumes per square metre of surface at all the Lake St. Clair and Lake Erie stations having a depth of more than 1.5 metres. I have used all the figures to the nearest tenth. The horizontal column 1.5—0 gives the volumes obtained by hauling the net from the depth of 1.5 metres, while the column bottom —0 gives the volumes obtained by hauling from the bottom. In this column I have used the average volumes as shown in the the table of averages.

No. of station	I.	II.	III.	IV.	V.	VI.	VIII.	IX.	XIII.	XIV.	XV.	XVI.	XIX.	XX.
1,5—0.	8,3	10,3	15,8	3,4	11,1	8,	9,4	7,6	7,1	8,9	7,5	7,1	44,1	36,3
Bottom —0.	18,4	10,3	18,4	5,	16,7	12,8	12,7	10,6	9,7	10,	10,9	9,6	57,4	40,8
Depth of bottom haul in metres	3,7	5,	5,5	2,5	5,3	4,8	4,4	4,3	2,2	2,9	5,2	4,6	4,4	8,4

If, now, I subtract the volumes of the column 1.5—0 from those of the column bottom —0, I shall obtain the volumes contained in columns of water extending from the bottom to a depth of 1.5 metres (bottom —1.5). By so doing I distinguish two strata, a *superficial* as before (1.5—0) and a *deep* (bottom to 1.5).

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* The negative numbers for the deeper strata of this table tempt to the further discussion of swarms, especially those of vertical migration. The numbers show clearly inequalities of distribution, but the greatest of these does not necessarily involve a variation of more than 25 % (as between hauls III^3 and III^2) — certainly not a considerable swarm. The data do not seem to me sufficient to warrant an extended discussion.

In the following table this subtraction is carried out and the volumes contained in the superficial stratum are transferred directly from the preceding table.

No. of statton - - -	I.	II.	III.	IV.	V.	VI.	VIII.	IX.	XIII.	XIV.	XV.	XVI.	XIX.	XX.
1,5—0 - - - - - - -	8,3	10,3	15,8	3,4	11,1	8,	9,4	7,6	7,1	8,9	7,5	7,1	44,1	36,3
Bottom—1,5 - - - -	10,1	,0	2,6	1,6	5,6	4,8	3,3	3.0	2,6	1,1	3,4	2,5	13,3	4,5
Thickness in metres of deep stratum - -	2,2	3,5	4,	1,	3,8	3,3	2,9	2,8	,7	1,4	3,7	3,1	2,9	6,9

The lower horizontal column gives for each station the thickness of the deep stratum in metres, as obtained by subtracting from the depth of the bottom haul the thickness (1.5) of the superficial stratum. In this table the superficial stratum is 1.5 metres thick while the thickness of the deep stratum varies as shown in the lower horizontal column.

In order to compare the strata with one another, I must express the quantity of plankton in volumes per cubic metre of water. To do this I divide the volumes as given in the line 1.5—0 by 1.5 and those given in the line bottom to 1.5 by the numbers which are given in the lower line and which express the thickness of the deep strata at the various stations. The results of this division to the nearesttenth appear in the following table:

No· of station - - -	I.	II.	III.	IV.	V.	VI.	VIII.	IX.	XIII.	XIV.	XV.	XVI	XIX.	XX.
1,5—0 - - - - - - -	5,5	6,9	10,5	2,3	7,4	5,3	6.3	5,1	4,7	5,9	5,	4,7	29,4	24,2
Bottom—1,5 - - - -	4,6	,0	,65	1,6	1,5	1,5	1,1	1,1	3,7	,8	,9	,8	4,6	,65
Depth in metres -	3,7	5,	5,5	2,5	5,3	4,8	4,4	4,3	2,2	2,9	5,2	4,6	4,4	8,4

It thus appears that there is a much larger volume of plankton in the superficial stratum than in any equal part of the deep stratum. It is also evident from this table that, in the superficial stratum, the absolute volume of plankton per cubic metre of water is nearly the same at all the deeper Lake St. Clair stations. With the exception of station III this volume does not vary greatly from 5 c. c. This uniformity is remarkable in view of the variations in the conditions of light and weather for the different hauls.

In order to avoid fractions I may multiply each of the volumes in the above table by 1000 and the figures thus obtained express the volume in cubic millimetres instead of in cubic centimetres. This multiplication is carried out in the following table:

No. of station - - -	I.	II.	III.	IV.	V	VI.	VIII.	IX.	XIII.	XIV.	XV.	XVI.	XIX.	XX.
1,5—0 - - - - - - -	5500	6900	10500	2300	7400	5300	6300	5100	4700	5900	5000	4700	29400	24200
Bottom—1,5 - - - -	4600	0	650	1600	1500	1500	1100	1100	3700	800	900	800	4600	650
Depth in metres -	3,7	5,	5,5	2,5	5,3	4,8	4,4	4,3	2,2	2,9	5,2	4,6	4,4	8,4

In order to see the relation between the volume in the superficial stratum and that in the deep stratum, the volume given for the deep stratum at each station may be taken as 1 and both volumes given for that station may be divided by it. The results of such divisions appear in the following table:

No. of station	I.	II.	III.	IV.	V.	VI.	VIII.	IX.	XIII.	XIV.	XV.	XVI.	XIX.	XX.
1,5—0	1,2	∞	16,	1,4	4,9	3,5	5,7	4,6	1,3	7,4	5,5	5,9	6,4	37,2
Bottom—1,5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Depth in metres	3,7	5,	5,5	2,5	5,3	4,7	4,4	4,3	2,2	2,9	5,2	4,6	4,4	8,4

From this table it appears that at Station I there was 1.2 times the volume of plankton in each cubic metre of the surface stratum as in an equal part of deep stratum, while at Station III there was 16 times as much. Stations II shows an enormously greater quantity in the superficial stratum. These two stations were in deep and comparatively clear water and they are also the stations in which the deep hauls show the greatest amount of difference from the average. Whether there was at these two stations a *local* accumulation of plankton at the surface, i. e., a swarm, due to vertical migration or whether at this time the plankton was accumulated at the surface uniformly over the whole lake, can not be satisfactorily determined from our observations. The observations at Station IV were made on the same day, but the water is here much shallower and there is therefore, not so much plankton to be accumulated at the surface. It would require more observations than we made at these two stations and others in the immediate neighborhood to determine the cause of the enormous difference between the surface and deep plankton. The differences at the other Lake St. Clair stations do not cover a very wide range, running from 1.3 to 7.4.

IV. ***There is about three times as much plankton in Lake Erie in the neighborhood of Put-in-Bay Islands, as in Lake St. Clair.*** The average of the Lake St. Clair stations is 3.03 c. c. per cubic metre of water. The four bottom hauls made in Lake Erie in the neighborhood of the islands are as follows:

XIX Q	9.21	Average 8.98
XIX	17.05	
XX	4.81	
XX Q	4.86	

These hauls were made on a day following a severe gale. As a result of this the water of the lake was nearly everywhere roiled as far as one could see. The wind was from the northwest and the hauls were made in the lee of islands, in situations where the water had not been roiled by the waves, but was as clear as usual.

At Station XXI, which was selected so as to be at a distance from the land, there was found in water 9.4 metres deep, 1.14 cubic centimetres of plankton per cubic metre.

It seems thus that the relative abundance of plankton in Lake Erie does not extend over the whole lake but is confined probably to the region of islands or favorable shores. Possibly the places at which our hauls were made are usually protected from wave action and are therefore favorable, but this does not seem to me likely.

The amount of plankton taken at these two Lake Erie stations is not sufficient to raise them above the category of plankton-poor lakes. To be called plankton-rich, the lake should yield perhaps ten times the plankton found in it at the most favorable place.

Our knowledge of the plankton of the Great Lakes may be thus summarized:

I. The volume of plankton in Lake St. Clair and Lake Erie in September is relatively small. They are *plankton-poor lakes.*

II. The plankton of Lake St. Clair is distributed with great uniformity. Swarms of horizontal migration, if they exist, are of rare occurrence.

III. There is constantly much more plankton in the superficial stratum of water, 1.5 metres thick, than in any equal portion of the deeper water.

IV. There are no constant differences to be detected in the distribution of the plankton at the different depths in a stratum of water extending from a depth of 1.5 to a depth of 5.5 metres.

V. The plankton of Lake St. Clair contains large numbers of individuals of *Clathrocystis æruginosa* and also of *Dinobryon* of two species. The individuals of these two species are so abundant as to have been usually recorded in our tow blanks as "many."

VI. *Chydorus sphæricus* O. F. M. is pelagic in considerable numbers in Lake St. Clair.

The statements as to quantity, under V and VI are estimates, not measurements. Apstein (94) calls the plankton-rich lakes Chroococcaceæ lakes and the plankton-poor lakes Dinobryon lakes and assigns to them the following characters:

	Chroococcaceæ Lakes.	*Dinobryon Lakes.*
Chroococcaceæ,	numerous,	scarce.
Dinobryon,	scarce or lacking,	numerous.
Chydorus,	pelagic,	littoral.
Plankton,	rich,	poor.
Water,	turbid	clear.

A similar list of the characters of Lake St. Clair stands as follows:

	Lake St. Clair.
Chroococcaceæ (Clathrocystis),	*numerous.*
Dinobryon,	numerous.
Chydorus,	*pelagic.*
Plankton,	poor.
Water,	*turbid* (probably through inorganic particles in suspension.

The characters in italics are those of Apstein's Chroococcaceæ lakes, those in Roman are those of his Dinobryon lakes. From this it appears that Lake St. Clair unites in about equal parts the characters of the two classes of lakes recognized by Apstein.

I turn now to the question of final "utility" of our work. I have already said that, as it seems to me, the only satisfactory solution of the many *perplexing problems of* the fisheries and fish culture must arise out of an untramelled investigation of all the facts involved with a view to the fixing of *principles*. These principles will, then, guide and unify practice. It should be remembered that such work is slow, that it requires the co-operation of many specialists and that it is expensive. I believe it to be nevertheless, an inexorable condition of progress.

I take up the practical bearings of our work, under several heads which refer to the general conclusions reached by us.

1. The lake is very poor in plankton. There are in the lake no fish, at least none of marketable size, that feed upon the plankton. The "herring" of our inland lakes (*Coregonus artedi*) feed upon the plankton and perhaps the herring of the great lakes have the same habit. It is not likely that the herring could thrive at all in Lake St. Clair; it certainly could not exist there in considerable numbers. No fish feeding upon plankton could thrive in this lake, so that the question of introducing such fish is at once answered in the negative.

If the lake were smaller it might be possible to fertilize it by the use of manures and other fertilizers so as to greatly increase its yield of plankton. The relatively large volume of water flowing through it will probably always prevent the use of fertilizers, since these would be speedily carried out of the lake through the Detroit river.

2. The bottom flora and fauna of the lake are abundant. From this it follows that if any fish are to be introduced they should be such as thrive on the minute animals which inhabit the bottom vegetation (snails, Sphæriums, Amphipoda, etc). Carp have been planted in ponds connected with the rivers which empty into Lake St. Clair and have made their way into the lake. They are already being taken by the fishermen in paying quantities and are of unusually fine quality. They probably feed on some of the minute bottom forms in the lake. It seems to me likely that these fish will be of increasing commercial importance. Other fish of similar food habits should be looked for with a view of testing their adaptability to this lake.

3. Although, so far as I know, no whitefish fry or whitefish eggs have ever been taken in the lake, nevertheless there is good reason to believe that these fish spawn there. The whitefish pass up the Detroit river in November for the purpose of spawning and were formerly taken in the lake and in the St. Clair river in considerable numbers. This affords ground for the assertion that the fish spawn here. But the method or place has not been observed.

Borne (87) has collected the observations made by various persons on the spawning habits of the European *Coregoni*. From this it appears that some species spawn on *Chara* beds, others on gravel or sand. Considering the great expanse of the *Chara* beds in Lake St. Clair it seems to me likely that our Lake Erie whitefish spawns upon these beds. It is not impossible that it should spawn on the gravel or sandy strip of bottom which in some places, as at Grosse Pointe, extends along the shore in water shallower than that in which *Chara* grows. This, however, seems to me unlikely, for the reason that the current is rather rapid in such places and would tend to carry the eggs away unless they were covered by the sand or gravel of the bottom. It is known, however, that the whitefish spawn in water of considerable depth and that the eggs are cast while the fish leap above the water in pairs. (For a collection of such instances, see the paper by the writer in the Report of the Michigan Fish Commission *for 1891–92, on* "The Ova and Spermatozoa, etc.") The eggs thus cast would be spread over a considerable area of the bottom and could not be very well buried by the adult fish.

If then, the eggs are laid over the *Chara* bed, the young fish would probably feed among the *Chara*, as is the habit of one of the European species (see Borne 87). It would not then feed upon the plankton, as suggested by Forbes (83).

The best practice in planting the whitefish would then consist in scattering the eggs, just before they are ready to hatch, over a considerable area of the lake bottom. The newly hatched fish would then find themselves at once in congenial surroundings. Instead of planting eggs, the fry themselves might be spread over the bottom by suitable devices.

Of course the only safety lies in determining by observation the character of the bottom in the place in which the whitefish deposits its eggs. This may differ in different lakes. But in the meantime, we cannot do better than to guide ourselves by such light as we have. Thus it seems to me that for Lake St. Clair the *Chara* beds are indicated as the spawning ground and that the method of planting above referred to is the most promising.

The "practical conclusions" may thus be summarized:

I. Lake St. Clair is unfavorable for plankton eating fish, such as the inland lake herring.

II. It is favorable for bottom feeding fish.

III. The whitefish eggs are probably deposited in the lake on the *Chara* beds. The eggs or recently hatched fry should, until further investigation, be "planted" by scattering them over a considerable area of the *Chara* covered bottom.

NOTE.—Owing to the absence of Prof. Reighard in Europe, the Mss. of this report was left in my charge with the very generous provision that changes should be made th any extent necessary to express the views of the writer or the evident conclusions to be deduced from his observations. Most changes have been purely verbal; but to avoid misunderstanding and possible charge of oversight, it seems best to add some further words in regard to the distribution of the plankton as shown by the tables on pages 34 and 35 of this report. The very variable amount of plankton in the lower strata as shown by the subtraction method, e. g., in the stratum 4.5—3 m. as —4.4 cc. for station III. and as 3.9 cc. for station XV., both of nearly equal depth, and the reverse relation of 5.4 cc. to —3.0 cc. in the next deeper stratum of the same stations,—this variation of nearly 50 per cent of the total amount of the haul within less than one-fourth of its depth does show clearly an unequal, and as further examination of the tables proves, *variable* distribution of the total plankton.

Thus far no one has attempted to define the word "swarm" nor show how far such a phenomenon as he conceives a "swarm" to be would affect the volume of the plankton; especially is this true of the limnoplankton where the forms concerned are throughout minute and the modifying effect will depend absolutely on the idea in mind. In other words, if one conceives the swarm to be a small, not very crowded aggregation of a few dozen individuals, the total volume might not be largely affected by its inclusion in the net; if, however, it is thought to be a crowded mass of thousands, the result will be different. Now while the evidence in the table will clearly permit of the first view, it will not in Prof. Reighard's mind support the second, since the considerable differences are the rare exception. Hence "swarms," if so defined, are the exception, not the rule; and it is unexpected to find so close agreement in the masses of the hauls as the table on page 33 shows. Moreover, the varying amount of the plankton in the different (artificial) strata below the top can by no means be regarded as evidence of the existence of swarms; it may be equally well explained on the ground of the partial or total absence of all forms at that particular zone, a phenomenon due to migration, to the effect of light, currents, or food supply at that point. It seems clear that there is great need of evidence in the shape of accurate enumeration of each species in each particular haul and in hauls with a closable net in order to establish the limits and vertical movements of each species for itself. The problem is by no means so simple and so uniform as some would have us believe.

HENRY B. WARD.

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APPENDIX I.

LIST OF THE PROTOZOA AND MOLLUSCA OBSERVED IN LAKE ST. CLAIR IN THE SUMMER OF 1893.

BY FRANK SMITH, INSTRUCTOR IN ZOÖLOGY, UNIVERSITY OF ILLINOIS, CHAMPAIGN, ILL.

1. Protozoa.

Protozoa occurring in surface collections:

Difflugia globulosa Duj., abundant.
Arcella vulgaris Ehr., scarce, only empty shells.
Actinophrys sol Ehr., scarce.
Dinobryon sertularia Ehr., abundant.
Dinobryon sp., frequent.
Peridinium tabulatum Ehr., scarce, only empty cuirasses.
Ceratium hirundinella O. F. Müll., abundant.
Stentor sp., scarce.
Codonella cratera Leidy, frequent.
Vorticella sp., on *Diatom* sp. and on *Sphaerozyga polysperma*, abundant.

Protozoa occurring in bottom tow and dredgings:

Difflugia globulosa Duj., scarce.
Peridinium tabulatum Ehr., scarce.
Ceratium hirundinella O. F. Müll., frequent.
Amphileptus gigas C. & L., scarce.
Stentor sp., abundant.
Vorticella campanula Ehr., frequent.

Protozoa occurring in shallow water among algæ:

Amoeba proteus Leidy, scarce.
Difflugia acuminata Ehr., scarce.
D. corona Wallich, frequent.

D. globulosa Duj., frequent.
D. lageniformis Wall. (*urceolata* Carter), scarce.
D. pyriformis Perty, frequent.
Lecquereusia spiralis Lecl., scarce.
Centropyxis aculeata Ehr., abundant.
Arcella dentata Ehr., scarce.
A. vulgaris Ehr., abundant.
Stylobryon petiolatum Duj., scarce.
Euglena acus Ehr., scarce.
E. oxyuris Schmarda, frequent.
Phacus longicauda Ehr., frequent.
Nassula ornata Ehr., frequent.
Amphileptus gigas C. & L., frequent.
Stichotricha Mülleri Lach., scarce.
Epistylis plicatilis Ehr., frequent.
Vaginicola gigantea D'Udk. scarce.
Cothurnia operculata Grub., scarce.
Pyxicola constricta Stokes, frequent.
Ophrydium versatile O. F. Müll., frequent.
Podophrya cyclopum C. & L., scarce.

II. Mollusca.

Limnea stagnalis L. Rushes near stave mill, St. Clair Flats; Salt Creek, abundant.

L. reflexa Say. Rushes, logs near stave mill, abundant.

L. reflexa zebra Tryon. Rushes, abundant.

L. palustris Müll. Rushes, logs near stave mill, frequent.

L. catascopium Say. Rushes, logs near stave mill. Sta. XVII, frequent.

L. humilis Say. Logs near stave mill, scarce.

L. galsana Say.

Physa gyrina Say. Logs near stave mill, frequent.

P. heterostropha Say. Rushes, logs near stave mill. Lake bottom generally, abundant.

P. integra Hald. Logs, stave mill, scarce.

Planorbis trivolvis Say. Rushes, logs near stave mill. Lake bottom generally, abundant.

P. bicarinatus Say. Rushes, Sta. XVI and XVII, frequent.

P. campanulatus Say. Rushes, logs near stave mill, abundant.

P. parvus Say.

P. albus Müll. Logs near stave mill, frequent.

Ancylus parallelus, Hald. Rushes, abundant.

Valvata tricarinata Say. Dredgings, abundant.

Campeloma decisa Say. Dredgings, occasional.

Amnicola limosa Say. Dredgings and bottom tow, abundant.

Pleurocera subulare Lea. Rushes, logs near stave mill. Dredgings and bottom tow, abundant.

P. elevatum Say. Dredgings, scarce.

Goniobasis depygis Say. Station VIII.

G. livescens Mke. Rushes, logs near stave mill. Dredgings, abundant.

Unio alatus Say. In rushes near stave mill. Sta. IV and XVII, abundant.

U. circulus Lea. In rushes near stave mill. Sta. IX, frequent.

U. coccineus Hild. In rushes near stave mill. Sta. XVII, abundant.

U. ellipsis Lea. Sta. IX, scarce.

U. gibbosus Bar. In rushes near stave mill. Sta. IV, XVI and XVII, abundant.

U. gracilis Bar. In rushes near stave mill, scarce.

U. luteolus Lam. In rushes near stave mill. Sta. I, II, III, IV, XVI, and XVII. Dredgings everywhere, abundant.

U. nasutus Say. In rushes near stave mill. Sta. XVI and XVII, abundant.

U. novi-eboraci Lea. . Scarce.

U. occidens Lea. In rushes near stave mill, frequent.

U. phaseolus Hild. Sta. IV, scarce.

U. rectus Lam. In rushes near stave mill. Sta. IV, IX, and XVII, abundant.

U. triangularis Lea. In rushes near stave mill. Sta. XVII, scarce.

U. undulatus Bar. In rushes near stave mill, scarce.

U. ventricosus Bar. In rushes near stave mill. Sta. III, IV, and XVII, abundant.

Margaritina deltoidea Lea. In rushes near stave mill, scarce.

M. rugosa Bar. In rushes near stave mill. Sta. IV, scarce.

Anadonta Footiana Lea. In rushes near stave mill. Sta. III, IV, XIII, XV and XVII, abundant.

A. Footiana subangulata Auth. In rushes near stave mill. Sta. II and one mile south of Lab., frequent.

A. subcylindracea Lea. Sta. III, scarce.

Sphaerium simile Say. In rushes near stave mill. Quite generally on bottom, abundant.

S. striatinum Lam. In rushes near stave mill. Quite generally on bottom, abundant.

APPENDIX II.

A REPORT ON A COLLECTION OF CLADOCERA, MOSTLY FROM LAKE ST. CLAIR, MICHIGAN,

WITH A TABLE OF SPECIES.

BY E. A. BIRGE, PROFESSOR OF ZOÖLOGY, UNIVERSITY OF WISCONSIN,
MADISON, WIS.

The collection of Cladocera which was given me for examination by Prof. J. E. Reighard, of the University of Michigan was contained in seventy-two bottles, of which fifty-two were from Lake St. Clair and the rest from various localities in Michigan. Of the 20 scattering specimens, thirteen contained no Cladocera and one bottle from Lake St. Clair was without any specimens.

The collection as a whole presents few noteworthy peculiarities. There are no new species and many of the forms usually found in our smaller and larger lakes are absent. The table, which comprises most of the report, must be construed as a report on the collection and not as representing, either in quality or quantity, the fauna of the region from which it came.

In addition to the bottles there was a collection of slides of mounted specimens. They contained a specimen of *Polyphemus pediculus*, which was not found in the bottles and a large species of *Chydorus*, apparently new but which is not described at present, as I wish to see fresh specimens.

The most striking features of the Lake St. Clair collection are: 1, the abundance of *Sida crystallina* which occurs in twenty-eight of the fifty-two bottles; 2, the constant presence of *Bosmina longispina* and the absence of all other species of the genus; 3, the abundance of *Monospilus tenuirostris*, which occurs in more than one-third of the bottles, and which was found in both sexes. I believe that no other collector has reported such an abundance of this species. The mode of collecting is probably the cause of this plenty, rather than any peculiar distribution of the species. Considering the shallow nature of the lake, it is surprising that no more forms of Lynceidæ were captured. The number of species is small and the number of individuals is still more scanty. It is also strange that no representatives of the genera Ceriodaphnia, Simocephalus, *and Scapholeberis,* were found.

NOTES ON INDIVIDUAL SPECIES.

Daphnia pulex var. pulicaria. This variety, established by Prof. Forbes include transparent forms of *D. pulex*, is of wide distribution. It is found in pools and in clear water as well, and the forms are hardly distinguishable. I have found it also in cisterns and wells. Morphologically it is very close to *D. pulex* but it is never yellow. In muddy waters it is sometimes grayish and somewhat opaque, but in color grades into perfectly clear forms. *D. schoedleri* is a very closely allied species if not identical.

D. kahlbergiensis Schldr, var. *intexta*, Forbes. This variety with smaller crest than the true *retrocurva* was present in many bottles. It was, however found to grade into *retrocurva* and very possibly is not a valid variety. The species is everywhere extraordinarily variable.

Acropreus leucocephalus Koch. This species varied a little from the regular form. It approaches somewhat toward *A. harpæ* Baird, but there seemed no good reason for separating it as a distinct species or even variety. The same may be said of *Camptocercus rectirostris*.

Alona lineata Fischer. The species which I have thus described is evidently the same that others have called *A. intermedia.* In terming it *lineata*, I have followed Matile, whose figure of the post-abdomen exactly agrees with my specimens. These species of *Alona* need careful revision, as indeed do all the larger genera of the *Cladocera.*

Chydorus sphaericus O. F. M. This species was always present and in a very small variety, probably that called *C. minor* Lillj. by Sars. I have not been able to find any constant distinction between this and the regular *C. sphaericus* except in size.

Monospilus tenuirostris, Fischer.

This species is evidently widely distributed in the United States. It has been found from localities as far separated as Isle Royale and Easthampton, Mass., a distance of about 1,000 miles. The limicolous habit of the animal renders it a rare form in any collection. It was, however, unusually abundant in the Lake St. Clair bottles and both sexes were present. The male has not been described before and is therefore described in detail.

Male.—Length, 0.35 mm.; height, 0.23 mm. The general shape is oval, recalling that of an *Alona.* The dorsal regions of the carapace is marked by oval depressions as in the female. The cast shells remain attached to the animal, as many as three having been seen in one case. The post-abdomen is more slender than in the female and is armed by fine hairs only. The teeth found in the female are wanting. The vas deferens terminates in a projection in front of the caudal claws, somewhat similar to that seen in *Alona guttata* Sars. The first foot is armed with a stout hook, not dissimilar to that found in most of the Lynceidæ. The macula nigra is large and triangular in form. There is no trace of the eye.

In another paper I called attention to the resemblance between *Monospilus* and *Alona.* The male shows this resemblance in a still more striking way. Were it not for the absence of the eye it might easily be taken for an *Alona*, especially in small individuals where there are no adherent old shells. It seems therefore very probable that we are right in regarding *Monospilus* as an *Alona*, altered in structure for a limicolous mode of life.

----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	No Cladocera.					----	----	----	----	----	----	11-Tow, Ludington, 7 ft.
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	No Cladocera.					----	----	----	----	----	----	(1)-Tow, Surface, Detroit R.
----	----	----	----	----	----	----	----	----	----	----	C.? s.	----	----	----	----	----	----	----	----	----	----	----	No Cladocera.					----	----	----	----	----	----	(2)-Tow, 10 ft., Detroit.
	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	+	----	----	----	----	----	----	----	+	----	+	----	----	----	----	----	I-Bottom Tow B.
	----	----	+	----	----	----	----	----	----	----	----	----	+	----	+	+	----	----	----	----	----	----	----	----	----	----	+	----	----	----	----	+	----	II-Bottom Tow A.
		----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	+	----	----	----	----	----	----	----	----	----	----	----	----	+	+	----	[illegible]

EXPLANATION OF THE TABLE OF SPECIES.

A cross (+) following a specific name indicates a specimen mounted on a glass slide. Other specimens were in alcohol.

C. S. indicates that cast shells only were observed.

The columns in which the Roman numerals appear in the headings show the Cladocera taken in the summer of 1893 in Lake St. Clair, Detroit river and Lake Erie. The Roman numerals indicate the stations. The words following the station number indicate the net used in making the haul. These nets are described in the report. The word plankton following the station number indicates the use of the vertical plankton net. Of the hauls not indicated by Roman numerals, those contained in the first seven columns are from certain inland lakes of Michigan, the names of which are given. They were made in July, 1891. Those in columns 8–18, inclusive, are from hauls made at the north end of Lake Michigan in April, 1893, at the localities indicated. In all these cases, an ordinary muslin tow net was used. The number of feet given in each column indicates the depth at which the tow net was run. When no number is given it was run at the surface.

APPENDIX III.

A PRELIMINARY REPORT ON THE WORMS (MOSTLY PARASITIC) COLLECTED IN LAKE ST. CLAIR, IN THE SUMMER OF 1893.

BY H. B. WARD, ASSOCIATE PROFESSOR OF ZOÖLOGY, UNIVERSITY OF NEBRASKA.

In the work done on the fauna and flora of Lake St. Clair during the summer of 1893, the group of Vermes was entrusted to the writer. The following is submitted as a preliminary report on the ground covered, the material obtained, and the results of this branch of the work so far as they can be seen at this stage.

Excluding the Rotifera, which were studied by another member of the party, the Vermes are represented in fresh water by three great classes: the Plathelminthes (Flat-worms), Nemathelminthes (Round or Thread-worms), and the Annelida (Segmented-worms). A synopsis of these classes gives the following orders occurring in fresh water:

Plathelminthes	Turbellaria.
	*Trematoda (Flukes).
	*Cestoda (Tape-worms).
Nemathelminthes	*Nematoda (Thread-worms).
	*Gordiacea (Hair-snakes).
	*Acanthocephala.
	Nemertini.
Annelida	Oligochaeta ("Earth-worms").
	Hirudinea (Leeches).

The orders starred are found exclusively or very largely as endo-parasites, and the importance for fish culture of a full knowledge of these forms seemed to warrant the special attention which was paid to them; for it soon became evident that the amount of material was too great for one worker, so that the non-parasitic worms were collected only as occasion offered, while the parasitic forms were made the subject of special study.

To speak of the non-parasitic forms first: Of the Turbellaria only one vial with a dozen specimens was preserved, and these have been sent to Dr. W. McM. Woodworth of Harvard for determination. The following forms were found in the tow and entered in the blanks without being preserved: *Mesostoma Ehrenbergii, Vortex* sp. Aug. 6; *Planaria maculata* Leidy, Sept. 1.

The group of Nemertini, which is represented in the ocean by numerous large worms great value as fish food, yields in fresh water only a very few small forms. One species about 3 to 5 mm. in length and 0.5 mm. in breadth, was found rarely on the plants collected from the shallow water of Lake St. Clair. Of the fifteen so-called species of fresh water Nemertini listed by various authors, hardly one can be recognized from the data given, and probably all may be reduced to two or three.* More accurate descriptions of these forms are necessary before any identification can be made.

Of the *Hirudinea* twelve vials were put up and afterwards sent to Prof. R. Blanchard of Paris for study.

The *Oligochaeta* were entrusted to Dr. G. Eisen of the California Academy of Sciences who has made the following preliminary report:

"The collection of *Oligochaeta*, contained in 17 vials, comprises about 8 or 9 species principally belonging to purely fresh water forms. There is one specimen of a genus related to *Thamnodrilus*, and about a dozen specimens of a new genus belonging to the family of the *Lumbriculidœ*. The collection contains besides two species of *Stylaria*, one of *Bohemilla*, one related to *Pristina*, one to *Naidium*, and one *Chœtogaster*. These can only be properly determined, however, after dissection and sectioning. It is safe to say that most of the species are new to science. All the material is in first-class order well preserved with a view to anatomical and histological study. The collection was accompanied by many careful field notes and four sheets of detail drawings. A complete report will be made as soon as time permits."

My own attention was devoted particularly to the parasitic worms, both while collecting during the summer and in study then and since. In the tow was found but one helminth, a form which challenged attention the first of our stay. It is a free swimming *Cercaria*, closely allied to *C. mirabilis* Braun, having a prominent tail terminating in two flat blades at right angles to the main body. The *Distoma* is enclosed within the tail of the *Cercaria* which has then more or less the appearance of an anchor with wide flukes. From one to four of these were taken from both top and bottom tow every day from July 27 to August 5 when it suddenly ceased to be found. Efforts to find the intermediate and primary host were alike unsuccessful. This form differs considerably in size from those described by R. R. Wright and M. Braun and is probably a new species.

In shore collecting and dredging among the rushes in shallow water, immense numbers of *Gordius* were obtained. They belong to not more than two species. One specimen of *Mermis* was also found.

The bulk of the material collected consisted of fish parasites. Every day the fish brought from the nets were examined, and the parasites found were transferred to dishes of normal salt solution and provided with labels containing full details as to the host and the organ inhabited. This part of the work which I did personally at first was afterwards entrusted to D. Lydell who proved a most satisfactory assistant, and by whom the larger part of the collecting was subsequently done. The results of this examination of the fish were entered in a special blank which is here reproduced.

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* Compare Vaillant in the Zoölogischer Anzeiger, vol. xv, p. 125.

No.---------

Name--

Size.---------------------------*Age*--------------------------

Locality---

Examined by--*189*----

PARASITES FOUND.

NAME.	No.	Organ Inhabited.	Condition.	Remarks.

Notes:

Each of the parasites was then subject to superficial examination, notes of evident peculiarities in shape or color made on the blank, and the worms then preserved. For this purpose an alcoholic solution of corrosive sublimate or picro-sulphuric acid was employed, followed by treatment in grades of alcohol. Forms which could be identified at once were entered by name, others referred to by number, and all were put up in vials for future study. Those which were peculiar were studied at the time so far as possible, and notes and drawings kept for reference.

The total amount of this material collected was *Trematoda* 59 vials, *Cestoda* 43 vials, *Nematoda* 15 vials, *Gordiacea* 9 vials, *Acanthocephala* 39 vials; in which one vial represents one order of parasites from one organ of one host at one date, so that two species may be in one vial or two vials may contain the same species collected on different days or from different hosts or organs of the same host. The examination of the bottles has gone far enough to show that a few of the forms represent new genera, many are new species probably, and nearly all are new in this country or in these hosts. When worked up the entire collection will form a valuable contribution to American helminthology.

The parasites from each host were counted and the results entered in the blanks. This was naturally laborious and demanded considerable time; but it is believed that it will furnish important evidence on the frequence of the parasites such as is lacking in previous lists which, so far as I know, rarely contain information even as to the number of infected hosts among those examined. The subjoined table presents in concise form the results of this study. From the list of hosts given it will be seen that nearly or quite all the important food fish of the lakes were examined. As it was not possible at that time of year to obtain whitefish in Lake St. Clair, Professor Reighard was kind enough to make a special trip to Belle Isle in the fall when he examined ten of them and forwarded me the parasites obtained. They came in good condition and add materially to the completeness of the collection. In addition to the fish, a large number of fresh water mollusks were examined as well as a few gulls and turtles from the immediate vicinity. The results of this examination are appended to the table below. It may be mentioned that some well known parasites were not found, among others the thread worm which infests the muscles of the black bass; it does not seem to occur at this season in the bass from Lake St. Clair.

As might be expected, most of the parasites were found in some part of the alimentary canal; not a few occur encysted in the liver, and the body cavity and air-bladder harbored occasional specimens. In one instance (*Hiodon*) the only parasites found were in the body cavity; they are probably new to science and are *Trematoda* with the mouth and the single sucker at the middle of the ventral surface, in this like the *Gasterostomidæ*, but differing from that family in numerous particulars, especially the sexual organs and the absence of any modification of the anterior end. The structure of this form will be described in detail in another place.

Some interesting facts appear on examination of the table given. The number of hosts examined is in some cases too small for general statements but such are only tentatively included in general statements. In considering the abundance of parasites it may be said that those fish which contain less than ten parasites each may be regarded as practically free; these are species 2, 5, 8, 9, 12, 13, 14 (see note), 17, 19. On the other hand those containing more than one hundred are to be considered as badly infected. Such are 4, 6 and 15. Of 18, only one specimen was examined and the number cannot stand as an average. Three specimens of 6 were examined; two had about forty parasites each, the third contained 285 *Acanthocephala*, bringing the average above the hundred limit, but the number examined was evidently too small to warrant conclusions as to which was the exceptional occurrence, and this form may be set aside for the present. Of the others 4 and 15, *Amia* is not a food fish; the second, the small-mouth black bass, was, as the table shows, the most seriously infected of any fish.

It will be noticed in this connection that a comparison by number only is somewhat misleading. Not only is there a wide difference in volume, and hence in effect on the host, between different species of the same order, as e. g. one *Distoma* collected measured 17 x 1 mm., while the smallest was 1 x 0.2 mm., where the volume of the larger is more than 85 times that of the smaller; but it is also evident that one adult *Cestode* of moderate size is equal in volume to more than a hundred *Distomata*. A comparison by number omits also the important factor of the size of the host, and one can easily see that the 42 parasites of each sturgeon play a smaller part in its economy than do the six of each perch or pumpkin-seed. Having regard, then, to the size of the parasites and to the size of the hosts, the table gives a relative idea of the degree of infection.

Comparing the parasites within one host it appears that the *Cestodes* are most important only in 19 and 20; the *Acanthocephala* are distinctly *most prominent in 6, 7, 15,* and 16 while the *Trematodes* ruled in 4 and the

Nematodes in 17. In the other cases the number of parasites is either so small as to be unimportant or so nearly evenly divided that no one group could be called predominent. *Trematodes* alone were harbored by 10, 11, 13, *Acanthocephala* alone by 8 and 16. External parasites were rare, being obtained only in one instance, from the gills of the whitefish.

In the food of the fish is to be found of course the key to the distribution and frequence of parasites, and considerable time was spent in the study of this subject. The only extensive articles on the food of the American fresh water fish are those of S. A. Forbes in the Bulletin of the Illinois State Laboratory of Natural History, 1878–88. After collating the results given there it was evident that there is variation enough in the food of the same fish in different localities to influence materially the question at issue. Some of the statements given there directly contradict observations made last summer at New Baltimore so that it will be necessary to await the result of study on the fish foods collected by our own party.

All of the parasites found were obtained from organs which are removed in cleaning the fish so that they are not directly dangerous to man. Any influence must be indirect on the health of the food or in reducing the supply of the fish. As to the effect of the parasites on the host a few words may be said. In most cases the number is so small that they could not noticeably diminish the food supply of the host, especially in a season of abundant nourishment like the summer; and it is also probable that the irritation produced by movements of the parasites is immaterial. In a few cases, however, this is not true, and the great number found in *Micropterus dolomieu* must be a serious draft on the organism. The *Acanthocephala*, moreover, which are present here in such large numbers, are especially dangerous since they collect in such masses as to obstruct the alimentary canal and make their way out into the body cavity and up into the liver, in both of which places they were found repeatedly. The host would then be affected in more than one way and it may be seriously. At any rate the subject deserves the fullest investigation since it is one of the finest of our food fish which is threatened. I hope to be able to present further evidence on the influence of the parasites on the host at a later date.

Reference number.	Fish examined.					Parasites found.				
	Scientific name.	Common name.	No. infected.	No. free.	Total No. examined.	Total No.	No. of Trematoda.	No. of Cestoda.	No. of Acanthocephala.	No. of Nematoda.
1	Acipenser rubicundus Le Sueur	Lake Sturgeon	2	0	2	85	75	0	0	10
2	Ambloplites rupestris (Raf.)	Rock Bass	2	0	2	88	1	1	6	0
3	Ameiurus natalis [d] (Le Sueur)	Yellow Cat	1	0	1	19	17	1	1	0
4	Amia calva L.	Dog Fish	4	0	4	[a]3521	[a]3469	13	7	32
5	Aplodinotus grunniens (Raf.)	Sheep's Head	12	0	12	30	26	4	0	0
6	Catostomus teres (Mitch.)	Common Sucker	3	0	3	364	0	7	357	0
7	Coregonus clupeiformis (Mitch.)	White Fish	10	0	10	263	[e] 5	15	226	17
8	Cyprinus carpio L.	German Carp	2	0	2	5	0	0	5	0
9	Esox lucius L.	Pike	3	0	3	24	8	8	8	0
10	Esox masquinongy (Mitch.)	Muskallunge	1	0	1	15	15	0	0	0
11	Hiodon tergisus Le Sueur	Moon Eye	2	4	6	52	52	0	0	0
12	Ictalurus punctatus (Raf.)	White Cat	2	0	2	12	8	4	0	0
13	Lepidosteus osseus (L.)	Gar Pike	1	1	2	1	1	0	0	0
14	Lepomis gibbosus (L.)	Pumpkin Seed	4	0	4	[b] 24	6	[b] 1	6	[b] 11
15	Micropterus dolomieu (Lacép.)	Smallmouthed Black Bass	6	0	6	[c]1489	[c] 272	20	1194	3
16	Moxostoma aureolum (Le Sueur)	Lake Red Horse	2	2	4	154	0	0	154	0
17	Perca flavescens (Mitch.)	Yellow Perch	28	0	28	155	5	23	1	126
18	Roccus chrysops (Raf.)	White Bass	1	0	1	105	94	11	0	0
19	Stizostedion canadense (C. H. Smith)	Sauger	3	0	3	25	0	23	2	0
20	Stizostedion vitreum (Mitch.)	Wall Eye	6	0	6	227	0	96	130	1
	Total number of species, 20. Total number of individuals		95	7	102					
	Total number of species free from the parasite at the head of the column					......	5	6	7	13
	Total number of individuals free from the parasite at the head of the column					......	41	45	44	62
	Also examined:									
	Merula migratoria (L.)	Robin	1	0	1	7	[f] 7	0	0	0
	Larus philadelphia Ord.	Bonaparte's Gull	13	0	13	[g] 51	28	11	0	0
	Chelydra serpentina (L.)	Snapping Turtle	2	0	2	[h]250	0	0	0	[h]250
	Chrysemys marginata (Agassiz)	Mud Turtle	1	0	1	[i] 16	[i] 16	0	0	0
	Anodonta ovata Barnes Unio gracilis Lea	Mussel	[h]33	[h]17	50	k	k			

Names after Jordan, Manual of the Vertebrates, fifth edition, 1890.

[a] The number of Distomata in one specimen was estimated at 3,000; only one-third was counted with a result of 1,023.

[b] Also an indefinite number of cysts in the liver.

[c] The total number is too small since there was also an unknown (large) number of a very small Distoma, of which only a few were preserved and included in the figures given.

[d] Intermediate between A. natalis and A. nebulosus, having 23 rays in the anal fin.

[e] From gills of two specimens only.

[f] Distoma macrourum Rudolphi.

[g] Including 12 which cannot be assigned to any order at present.

[h] Estimated.

[i] Monostoma n. sp.

[k] The foot was filled with encysted Cercariea which have not been identified as yet. The number present in each specimen was almost incalculable. About two-thirds of the mussels were infected.

APPENDIX IV.

THE INSECTA AND ACARINA OF LAKE ST. CLAIR. A PRELIMINARY REPORT.

BY DR. R. H. WOLCOTT, ANN ARBOR, MICH.

The insect life of Lake St. Clair, as shown by the investigations carried on during the summer, is exceedingly abundant and of a very varied character, notwithstanding the fact that the larger number of individuals obtained in the various tows and dredgings belonged to a comparatively small number of common and widely diffused forms. Nearly every order of the Insecta was represented in the collections, as well as three of the families of Acarina or mites.

The species of Insecta of which specimens were preserved, are distributed as follows:

Pseudo-neuroptera—Odonata (Dragon-flies)	11
Ephemeridae (May-flies)	6
Perlidae (Stone-flies)	1
Neuroptera—Phryganidae (Caddis-flies)	15
Hemiptera (Bugs)	8
Coleoptera (Beetles)	5
Lepidoptera (Butterflies and Moths)	1
Diptera (Flies)	25

A total of 72 species represented by over 600 specimens, living either as adults or during their immature stages in the waters of the lake.

The single Lepidopterous larva collected was taken off the mouth of Salt Creek, is a species of *Hydrocampa*, one of the Noctuidae or owlet-moths, and probably fed on the water lilies, which abounded in the creek. The Diptera were largely of the families Culicidae and Chironomidae or mosquitos and gnats.

The number of specimens could have been materially increased had the object been the formation of a full collection. But the desire being more to study the life-habits of the various species, many opportunities to obtain specimens were sacrificed in the attempt to carry them through their transformations in the aquaria. This latter attempt was successful in so far that many valuable notes and drawings were secured, and specimens illustrating nearly the whole life-history of many species preserved. The identification of this material has proceeded but slowly and very incompletely owing to the lack of literature on the subject which renders the task exceedingly difficult.

Of the Acarina, a single specimen of the cheese mite (*Tyroglyphus*) was taken in a surface tow, its occurrence being, without doubt, accidental. Nine specimens of a species of horny mite (family Oribatidae), were found in bottom and surface towings in different parts of the lake. Of the Hydrachnidae or water mites proper, a very large number were secured, doubtless more than have ever before been collected in this country, the group being one which, so far as American forms are concerned, have been almost entirely neglected. The collection embraces 18 genera, 36 species, and 1,369 specimens, of which probably 3 genera and a score of species are undescribed.

The whole collection, therefore, includes 110 species and over 2,000 specimens, beside a few pinned specimens of dragon-flies, aquatic Coleoptera, etc.

The distribution of these throughout the lake is very general, its shallowness rendering it possible for many species to live anywhere that suitable conditions other than depth of water exist. This fact together with the gradual slope of the shores precludes the establishment of any well-defined faunal zones, and yet a general distinction may be observed between the littoral and pelagic faunas, the latter including those forms living in and over the growth of vegetation included in the Characetum, as defined by Mr. Pieters in his report upon the flora of the lake, the littoral species being found between this area and the shore line.

Among the littoral forms may be mentioned the majority of the larvæ of the dragon-flies, most of the Hemiptera, the larger part of the coleopterous forms, many Diptera, and a few phryganid and ephemerid larvae. The pelagic fauna is characterized by an abundance of ephemerid and phryganid species, a very few colepterous and hemipterous forms, a great number of Diptera, and the representatives of one genus of dragon-flies, *Gomphus*, together with a few of the other dragon-fly larvæ. It is interesting to note the greater abundance of predatory or carnivorous forms in the littoral fauna. The water-mites were distributed everywhere in the lake, except that a few of the forms whose swimming powers are feeble, were only detected in the marshy tracts along the shore.

The great abundance of insect life throughout the lake, and especially in the Characetum which carpets the bottom, and in which certain species are exceedingly abundant, would seem to render it probable that insect forms should constitute a considerable percentage of the animal food of the fish inhabiting the waters. And an examination of a number of fish stomachs collected by the expedition bears out this probability, as in them were detected an immense number of insect larvæ, especially of those forms living in the Characetum over which a large majority of the fish had apparently been feeding.

All the conditions of the lake, including the small depth of the water, the uniformity of its temperature throughout the year, and the abundance of vegetation, tend to favor the production and future continuance of this *great abundance of insect life* and thus to furnish food for a correspondingly *great abundance of fish* within the waters of the lake.

APPENDIX V.

SUGGESTIONS FOR AN EXPERIMENTAL METHOD OF DETERMINING THE EFFICIENCY OF QUANTITATIVE NETS.

BY J. E. REIGHARD.

The cloth used for our vertical net is the No. 20 bolting cloth manufactured by Dufour & Co. The net was constructed essentially like the one used by Hensen and described by Apstein in Zacharias' well known "Thier-und Pflanzenwelt des süssen Wassers."

The only essential modification was in the bucket, and is sufficiently clear from the illustration.

It was my purpose to determine the coefficient of the net by the use of the table given by Hensen (87). For the purpose of seeing whether the cloth used in our net was the same as that used by Hensen, I undertook to measure it. Pieces of the cloth were placed under a compressor and the image of 30 to 70 openings was projected onto cardboard by means of an Abbe camera. The openings were then cut out of the cardboard and the pieces thus obtained were weighed. By comparison of the weight thus obtained with that of a piece of cardboard of known area, it was easy to determine the areas of the openings in the cloth. The method is very accurate. Measurements made in this way resulted as follows:

	Av. areas of opening in fractions of a square centimetre.
1. On cloth as received from the dealer	.00003596
2. On cloth wetted and then dried	.00002808
3. On cloth that had been used for 40 hauls of a net	.00002336
4. On cloth of net used in summer, 1893	.00002548

I then asked Dr. H. B. Ward to make some further measurements for me. His first experiments on the net used in the summer of 1893 gave as the average area of the openings in square centimetres .00002637 and .00002235, which vary but little from the measurement given above for the same cloth. The third measurement, however, gave an average for the area of each opening of but .00001651 square centimetres, so different that he at once set about finding the cause of the variations. He observed on experimenting that slight changes in the tension of the cloth, or in the pressure exerted by the cover of the compressor in which the cloth was measured, produced immediate and considerable variations in the size of the openings. These results were instantly apparent if the changes were made while the observer was watching the cloth, and showed in the measurements as well.

It thus became evident that in order to compare two pieces of cloth they must be measured under identical conditions of tension, pressure, moisture, etc. Hensen (87) gives the average area of the openings in his No. 20 cloth as .000028387 of a square centimetre, but he does not state the conditions under which the cloth was measured. Without a knowledge of those conditions any accurate comparison of our cloth with his seemed quite impossible.

I, therefore, set to work to find some method by which I could measure the coefficient of my net by direct experiments and finally hit upon the following.

I had constructed a model of our large plankton net on a scale of .3 linear. This was an accurate copy of the original net in every particular and should therefore have the same coefficient. It was large enough so that the difference in the friction of the water at the various openings of it and the original net could be neglected.

A rectangular wooden tank about 2 metres high and 80 cm. on each side was constructed. Three openings 35 by 45 centimetres were cut in one side of this tank and three others at corresponding places on the opposite side. These windows were filled with plate glass. The tank was filled with water from a Pasteur filter and held about 622,000 c. c. of water. In this water was placed 30 grams of *Lobelia* seeds. These seeds had been previously cleaned of all impurities by decantation and had been boiled in water, then dried and weighed. They were thus thoroughly freed from soluble constituents and were of constant weight when dry. The seeds were well soaked in water before placing in the tank. They were found to be so nearly the specific gravity of the water that they remained in suspension in it for a considerable time; they are further about the size of the small Crustacea in the plankton. A long wooden paddle was prepared and to each side of this were tacked six zinc pieces which were so bent as to stand out at right angles to the surface of the paddle for a distance of six inches. By moving this paddle up and down in the water and by occasionally moving it sidewise it was found to be possible to keep the seeds uniformly distributed in the water of the tank. The distribution could be observed through the windows in the sides of the tank. There were usually more seeds near the bottom than near the top, but the horizontal distribution was uniform. Each cubic centimetre of water in the tank then contained on the average .0000471 grams of seed. While the seeds were thus uniformly distributed, the model net was drawn from the bottom of the tank to the surface of the water. It had an area of 100 square centimetres and traversed a distance of 160 centimeters in ascending. It thus passed through a column of water containing 160 by 100 or 16,000 cubic centimetres. This column would contain, therefore, 16,000 times .0000471 gram of seeds which is *.7536 gram.* The seeds taken in the net were dried and weighed. If the *net had strained the whole* column of water it should in the case assumed contain .7536 gram of seeds. It was found, however, to contain usually .4 to .5 gram. Hence the efficiency of the net is expressed by $\frac{.4}{.7536}$ or the coefficient is expressed by $\frac{.7536}{.4}$. The cord by which the net was raised was provided with two buttons which could be so set as to open an electric circuit when the net started from the bottom and to close the circuit when the net reached the surface of the water. The opening and closing of the circuit were recorded on a revolving drum and at the same time intervals of one-fifth of a second were marked upon the drum. There was thus kept an accurate record of the time of ascent of the net.

The coefficients obtained in this way varied from 1.5 to 2. They were found to be practically identical for any given velocity if the experiments were made on the same day. Slight clogging of the cloth, due to minute fragments of the seeds adhering to it, raised the coefficient considerably. The cloth was then washed by rubbing between the hands with soap and warm water. The result of the washing was to change the cloth visibly so as to reduce the size of the openings in it and to make the coefficient rise from 1.5 to 2.1.

The experiments were found to consume so much time that I was compelled to drop them. I believe the method to be accurate. It would be necessary during the course of experiments with it to measure the cloth by some method which would yield uniform results and such a method should be devised.

Having thus failed, for lack of time, to satisfactorily determine the coefficient of our net experimentally, I have assumed our cloth to be identical with that used by Hensen. I have no doubt that this assumption is correct, since the cloth is of the same number as Hensen's (No. 20) and does not agree at all with his No. 19. Furthermore the average area of the openings as determined by the experiments noted above, is not far different from that given by him for No. 20 and very unlike that of No. 19 in his list. On this assumption I had Mr. E. A. Lyman calculate the coefficients of our net at the different velocities used by us and give below the results.

Velocity cm.	Coefficient.	Total correction = coefficient x 8.08.	Velocity cm.	Coefficient.	Total correction = coefficient x 8.08.
30	5.557	44.92	65	2.18	17.61
36	4.25	34.34	67	2.14	17.29
40	3.38	27.31	68	2.12	17.13
43	3.14	25.37	69	2.10	16.97
46	2.89	23.35	70	2.08	16.81
50	2.57	20.76	71	2.07	16.73
51	2.54	20.52	73	2.05	16.56
52	2.51	20.28	74	2.04	16.48
53	2.48	20.04	75	2.03	16.40
55	2.42	19.25	76	2.02	16.32
56	2.37	19.15	78	1.99	16.08
58	2.32	18.75	80	1.98	16.00
60	2.26	18.26	81	1.979	16.00
61	2.24	18.10	87	1.97	15.92

These corrections I have made use of in calculating the volume of plankton per square metre of surface. It is quite possible that an average correction based on an average velocity of 63 cm. per sec. would have answered equally well. Indeed in two cases where recorded velocity was low, 30 and 43 cm., the application of the correction resulted in an absurdity as pointed out in the note appended to the schedule of hauls.

The hauls made through short distances yielded low velocities. At first I was inclined to attribute this to the fact that the time interval read off from the second hand of a watch would be likely to be overestimated, if the interval were short (2 seconds or less). The velocity would thus be made to appear less than it really was. If this were the case the application of the large correction demanded by low velocities would make the results too great for all the 1.5 metre hauls. If this were true, it would be better to make an average correction for all hauls. On reflection, however, I decided that the net traveling a short distance probably actually travels at a lower average velocity since it must start slowly. I have therefore corrected the volumes taken in all the hauls for the observed velocities except in the two cases already pointed out.